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THE ORIGIN OF RED BEDS

By PAUL D. KRYNINE*

Introduction. Red colored sediments have always attracted the attention of geologists. A venerable opinion of long standing connects red beds with aridity, thus investing them with an important paleoclimatic significance. Red beds are rather extensive, forming, for instance, close to 15 per cent of the Paleozoic section in the Appalachian region. The red bed problem has been extremely controversial, with marked differences of opinion, possibly due to the fact that the term "red bed" is a catchall for many sedimentary types produced under different conditions, the only common feature of them being the red color.

Source of Red Color. Red color in sediments is produced either by the presence of red minerals such as orthoclase or, more commonly, by the presence of red ferric oxide pigment occurring either as anhydrous hematite or as red limonite (turgite), in amounts as small as two or three per cent of the rock.

Red beds in the field show considerable variation of color. The amount of actual red rock within a markedly red bed series may be as low as 35 per cent. Many red beds do not carry more than ±50 per cent of actually red colored rocks. The balance consists of drab, gray, green, brown or even black colored rock units. The two basic shades of red are a deeper cherry red (a typical Triassic and Paleozoic color) and an orange red (generally more characteristic of the Permian). Red iron oxide pigment produces shades of purple when mixed with such green minerals as chlorite or glauconite.

Classification of Red Beds. Red ferric oxide pigment can permeate a sediment in a variety of ways. As a whole its presence indicates a prevalence of oxidation over reduction, a phenomenon that takes place most easily above the water table, thus explaining the great predominance of continental red beds over marine red beds. Otherwise, ferric oxide can enter almost any sediment and, hence, practically every normal sedimentary type may occur as a red bed facies. However, in certain sediments this red bed facies is much more prominent and frequent than in others.

Like all normal sediments, red beds can be divided into detrital and chemical. In *detrital* red beds, the red pigment entered the basin of deposition as a solid detritus, generally in the form of hematitic red clay. In *chemical* red beds, the red pigment is precipitated from solution within the basin of deposition. Finally, the red pigment may develop authigenically in the sediment itself, after deposition, through the oxidation of ferrous oxide. A pragmatic fourfold classification (not entirely logical, since it combines certain elements of all three preceding modes of entry) results in four basic types of red beds (FIGURE 1).

(1) *Red beds produced from red soils or primary red beds.* The red pigment is developed by weathering in the source area of the future sediment, at the expense of iron-bearing minerals (silicates or carbonates) and is incorporated directly into the resulting sediment. This can be done in three ways:

(a) After erosion and transport, producing Primary Detrital red beds.

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(b) By *local* reworking of the regolith, producing Primary Reworked red beds.

(c) By lithification of the regolith without hardly any reworking at all, producing Primary Residual red beds.

(2) *Red beds produced from non-red detritus by oxidation within the sediment itself.*

(a) Immediately after deposition and before burial, producing Post Depositional red beds.

(b) After burial, emergence and deep sub-surface oxidation producing Post Diagenetic red beds.

(3) *Red beds produced through the reworking of older red beds* or Second Cycle, or Secondary red beds (generally eolian or glacial, less commonly aqueous).

(4) *Red beds produced chemically by precipitation from a solution within the basin of sedimentation.*

(a) Under marine conditions.

(b) Under fresh water conditions.

(c) Authigenically and intrastratally by infiltration within the sediment.

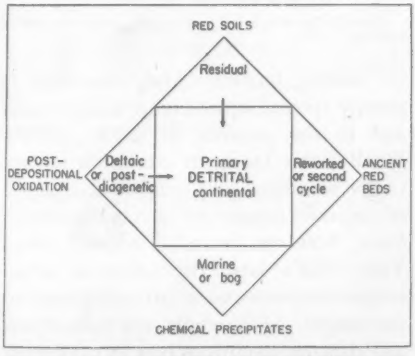

Figure 1. Classification of red beds, based on genesis and provenance of ferric oxide pigment.

Primary Red Beds: Detrital, Reworked and Residual

Significance of red soils. Primary red beds originate from red soils, thus implying a certain geomorphic and climatic picture in the source area (FIGURE 2). The required physiography consists of a reasonably well drained region, with a slope sufficient to maintain the soils in the zone of oxidation above the water table (slope possibly as low as several feet per mile). The climate necessary to produce red soils rather than brown or yellowish soils (meaning hematite and turgite rather than ordinary limonite) is as follows:

EXCESS OF OXYGEN = WELL DRAINED REGION

PRODUCES RED OR YELLOW COLOR

RED COLOR APPEARS AT 60° F. TEMPERATURE and >40" RAINFALL ON SILICATES or > 25" RAINFALL ON CARBONATES

Figure 2. Physiography and climate necessary for the production of red soils.

(1) For the red weathering of *silicates*, mean annual temperature above 60°F. and over 40" of annual rainfall.

(2) For red weathering of carbonates ("terra-rossa"), 55–60°F. of mean annual temperature and over 25" of annual rainfall.

At least 95 per cent of present day red soils are formed above 60°F. and 40". Most of the 5 per cent of so-called non-humid red soils were not formed at the present time, but were inherited from the pluvial Pleistocene period. The so-called "red sands of the desert" are mostly fiction in so far as the Recent goes, and are practi-

cally always produced by the reworking of the pluvial Pleistocene red soils or of ancient red sediments.

The intense weathering processes that produce limonite and hematite frequently, not only as red disseminated material, but also as ferruginous concretions, lead at the same time to the production of other stable products of weathering, such as hydromicas and particularly kaolinite and gibbsite.

Preservation of red color. The hematitic red clay formed in the regions of red soils is transported into basins of deposition and, if the red color is preserved, a red sediment follows. Preservation of red color implies only one fact, namely, the predominance of oxidation over reduction, a condition that can take place *under any climatic condition*. The controlling factor is a physiography which makes it possible for free oxygen to come in contact simultaneously with the ferric oxide and whatever organic matter incorporated in the sediment. If these conditions are satisfied, *i.e.* if deposition takes place above the water table, which is a feature of practically every well-drained interfluve or subaerial portion of a delta, then the chemical reaction involved is as follows (FIGURE 3):

$$Fe_2O_3 + C + O_2 = Fe_2O_3 + CO_2.$$

Thus, the organic matter gets oxidized and destroyed by an excess of oxygen without ever having had a chance to reduce the ferric oxide.

If, however, deposition takes place under the water table, meaning swamps, lakes, channel deposits, etc. then instead of the excess of oxygen there may be a deficiency and conversely a possible excess of organic matter, and the equation will be as follows:

$$2Fe_2O_3 + 2C = 4FeO + C + CO_2.$$

Thus, red ferric oxide is reduced to colorless ferrous oxide and the red color is lost. At this stage, since ferrous oxide is soluble, a certain amount of iron will be removed, or transferred to another part of the formation, where it may be re-precipitated as an iron carbonate.

In reality, the oxidation-reduction relationships are much more complex and relativistic than indicated by these schematic equations. An important factor is sufficient time for oxidation to take place

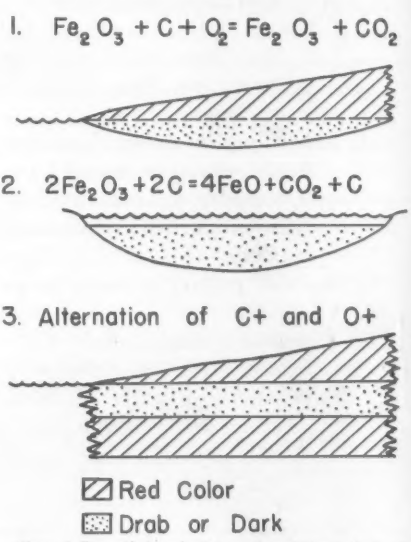

Figure 3. The oxidation-reduction reaction within the basin of deposition.

(a tectonic factor). Also, oxidation is greatly speeded up at higher temperatures and in the presence of much rainfall. Finally, this inorganic oxidation scheme can be translated into terms of destruction of organic matter by aerobic bacteria. Since, however, bacterial activity obeys Vant Hoff's law, the inorganic time-temperature-moisture relationship remains unchanged. As a whole, the geomorphic and climatic conditions best suited for the formation of red soils are also the best for

the preservation of red color in the resulting sediment.

Under normal tectonic subsidence, the surface of a basin of deposition may oscillate slightly, changing from a drained slope of deposition above the water table (one to two feet per mile are sufficient to maintain adequate drainage) into a submerged or semi-submerged basin. The layer formed above the water table may be red, but, if the basin then passes from the drained (open) to the undrained (closed) stage, the next layer will be colorless, green, gray or even black. However, the underlying (previous) red layer is not reduced, since the organic matter in it was already destroyed by previous oxidation (infiltration of reducing solutions from above is possible but rare). Another typical continental setup for the alternation of red and non-red layers occurs through the simultaneous existence of channel deposits, in which reduction takes place, and of interfluves or flood plain deposits in which oxidation predominates (FIGURE 4). Channel deposits are normally medium clastic sands, whereas the flood plain deposits are clayey silt. The lateral migration of these physiographic loci produces alternating gray sandstone and red shale or siltstone layers.

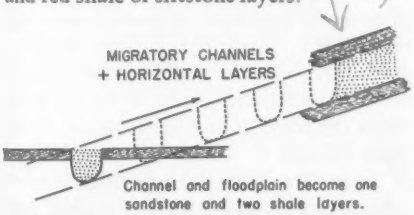

Figure 4. Formation of alternating red shale and gray sandstone layers through the migration of channels across a floodplain in space and time.

It can be seen, thus, that an arid climate is not required for the formation or preservation of red detritus. The concept of *absolute* oxidation (no organic matter, and hence a desert) or of *absolute* reduction (organic matter present and hence not a desert) is fallacious and must be replaced by the relative concept of fluctuating oxidation or reduction periods of adequate length due to a *relative* excess or deficiency of oxygen as against available organic material. The control is, hence, not so much climatic as physiographic, meaning tectonic. All available paleoclimatic criteria, fauna and flora, almost uniformly point to the existence of very hot and very *humid climates* during the formation and deposition of most primary detrital red beds.

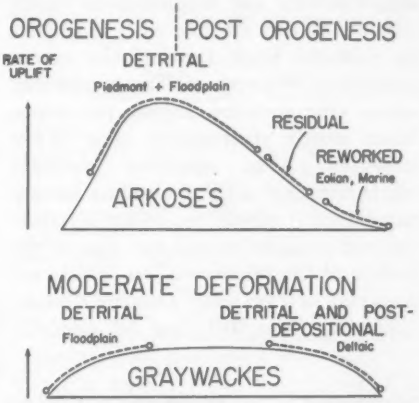

Figure 5. Relation of primary red beds to arkoses and graywackes during different substages of the orogenic and geosynclinal stages of the diastrophic cycle. Dashed lines show field of red bed occurrence. Arrows indicate amount and intensity of uplift and related subsidence.

Relation of primary red beds to normal sediments. Primary red beds normally are continental deposits, generally related to periods of strong orogenic activity, and, hence, to the large scale emergence of continents. Thus, they are normally associated with arkoses. The tectonic activity of the orogenic stage of the diastrophic cycle can be divided into a combined early tectonic and a main tectonic phase on one hand, and a gradually declining late- and post-tectonic phase, on the other (FIGURE 5). These phases are characterized respectively by tectonic arkoses occurring in

extremely thick deposits and by post-tectonic or residual arkoses occurring more frequently as small patches and thin broken blankets. Frequently, both of these arkose types are red, thus producing two major red-bed types: namely, the *primary detrital red beds* (generally red tectonic arkoses) and *primary residual red beds* (mostly sedentary arkoses).

Formation of arkosic red beds. Physiographically tectonic arkoses are formed essentially in the piedmont and upper-reaches of river plain systems. Lithologically they are thus characterized by many conglomerates and fanglomerates (since tectonic arkoses are frequently generated by powerful block faulting); by coarse sandstones, by a very small amount of true shales (the so-called arkosic red shales being mostly siltstones or even clayey sandstones). The operative erosional mechanism of an active fault block (or any rapid uplift!) implies two loci of weathering and erosion (FIGURE 6). One is the surface of the interfluves, on which red soils may develop under adequate climatic conditions (over 60°F. and 40″ rainfall).

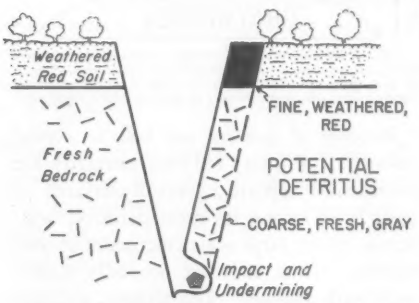

Figure 6. The V-shaped canyon, the basic geomorphic unit for the formation of red arkosic detritus.

If the climate is tropical humid, the red soil on these interfluves may be held rather solidly by vegetation and, hence, the absolute amount of material eroded from such interfluve is rather small, regardless of the fact that they may cover most of the area of an entire region. The other locus of erosion is the bottom of the very steep V-shaped canyons, which characterize such youthful topography. By undermining of the oversteepened banks, very large masses of fresh bed rock, completely non-weathered, may be eroded. The resulting mixture in a granitic source area will consist of a fresh, hardly weathered granitic detritus, coming from the bottom of the canyon; and hematite bearing, deeply weathered red clay, rich in kaolinite and possibly even carrying gibbsite, coming from the interfluve.

In the Triassic of Connecticut, these two petrographic end members, namely fresh granitic detritus and hematitic red clay, have the following average composition:

Granitic Detritus	*Red Clay*
Quartz 58%	Kaolin 60%
Microcline 31%	Gibbsite 6%
Sodic plagioclase 9%	Sericite-illite 12%
Mica 2%	Hematite 20%

The same mineral (microcline for instance) will be fresh and unweathered if it comes from the bottom of the canyon and deeply decayed if it comes from the interfluvial red soil. Such an association in one single specimen is quite diagnostic.

The deposition of this mixture takes place on the piedmont, where an unmixing takes place, with the coarser granitic detritus segregating itself into gray channel sandstones, while most of the red clay forms the red silts and shales of the flood plain (FIGURE 4). Since this unmixing is never perfect, a good bit of the channel deposits are colored red. Under even less favorable sorting a red clayey sandstone may be formed (the "Redstone" of Connecticut).

Examples of primary (mostly detrital) red beds. The Triassic Newark formation of the Eastern United States is a fine example of primary detrital red beds. It is found

for a length of 1,200 miles from South Carolina to Nova Scotia, and forms a series of extremely thick, prismatically shaped, faulted troughs of deposition, in which up to 15,000 or more feet of sediments may be present. The Triassic of Connecticut, studied in considerable detail by the writer, contains 52 per cent of actual red beds. The lithological breakdown is: Red sandstones 31 per cent, Red siltstones and shales 21 per cent, gray sandstones 41 per cent, dark shales 6 per cent.

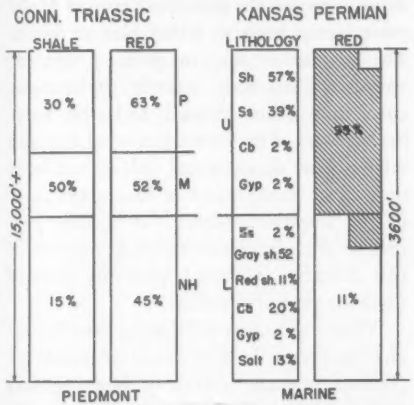

Figure 7. Comparative lithology and color distribution of two primary detrital red beds. The Connecticut Triassic (only shale percent shown, balance is sandstone and conglomerate) is piedmont and the Kansas Permian near shore marine. Triassic formations are: P—Portland, M—Meriden, NH—New Haven; Permian: U—Upper, L—Lower. Cb means carbonates: Data based on field work for the Triassic by P. D. Krynine and for the Permian by Ada Swineford.

During most of Triassic time, the bottom of the trough subsided at high speed, but the surface of deposition was a *well drained* slope of deposition, the sediments thus staying red. During Middle Newark time (Meriden epoch), however, the drainage was impounded by warping and extensive lakes and swamps developed producing dark shales (FIGURE 7).

Similar relationships exist in the Fountain formation of the Front Ranges, the Sespe of California and certain parts of the West Texas Permian. Sometime, sthese tectonic arkoses may stretch farther into the lower reaches of a river system, and even into marine near shore beds as in the Permian of West Texas.

Although the diastrophic cycle and tectonism control all sedimentary processes, nevertheless the actual formation of a sediment takes place within a certain locus of deposition (or environment). The relationships between certain typical red beds and the major classes of depositional loci are shown in FIGURE 8.

Graywackes are related to moderate deformations of the earth's crust and, hence, tend to be deposited typically in the deltas and lower river plains. Thus, the red beds connected with the graywackes are

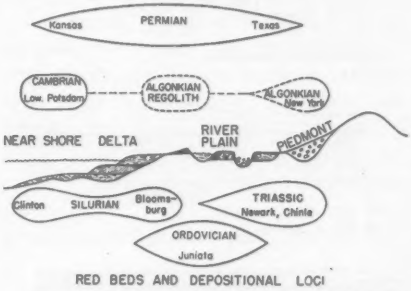

Figure 8. Relation of typical red beds to loci of deposition.

also deltaic or nearly so. Examples of this are many of the detrital red beds of the Paleozoic of the Appalachian region such as the Upper Ordovician Juniata formation, the Silurian Bloomsburg red beds, the Devonian Catskill, the Tertiary Siwalik of Northern India. Although most of the deltaic and flood plain detrital red beds are primary, nevertheless a certain amount of post-depositional exidation may reinforce the original red color.

The *quartzites* may also carry detrital red beds. However, since large scale quartzites of the Belt series or Potsdam type are formed under conditions of tectonic quiescence (which corresponds depositionally to gently subsiding peneplanes) the red

beds connected with these quartzites are generally of the *reworked* type. This means that the residual red beds developed in arkoses and, specifically, the red regoliths occurring on the peneplanes produced by erosion and planing of an orogenic region, may be incorporated into an advancing quartzitic marine sediment and color it red. The Pre-Cambrian-Potsdam contact north of the Adirondacks shows beautiful remnants of Algonkian (?) primary detrital red beds of the tectonic

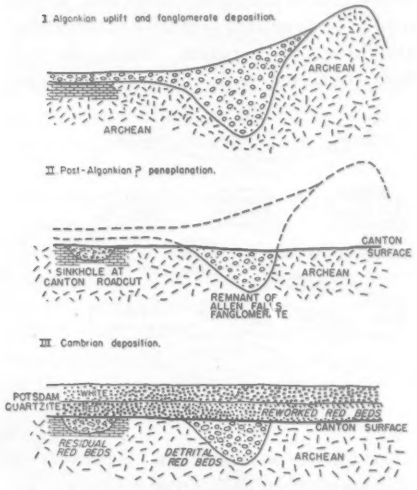

Figure 9. Early and late Algonkian and Cambrian paleogeography of New York State showing tectonic, residual, and reworked red beds, all of them primary.

fanglomerate arkosic type, morphologically non-distinguishable from the Connecticut Triassic. Side by side occur residual red beds of much later age, related to post-Algonkian peneplanation, and both of these are covered unconformably by still later, well rounded, Potsdam quartzites. The red iron oxide pigment from both the fanglomerates and regoliths has been mechanically incorporated into the basal quartzites, coloring them red and producing primary reworked red beds (FIGURE 9).

Post Depositional and Post Diagenetic Red Beds

An iron bearing sediment oxidized after deposition may turn red. This takes place on sub-aerially exposed interfluves of deltas and may change blue and green to red. The submerged part of the delta stays green and, if the movements are oscillatory, an alternation of red and green beds takes place. Such red beds differ from primary detrital red beds in that oxidation has taken place *locally* after deposition and the basic background of the entire series remains either blue or green. The reverse is true in primary detrital variegated red beds, namely the non-red color has been reduced and the basic background of the formation is red to begin with. Post depositional deltaic red beds on a basic background of blue clays exist in the Irrawaddy delta. A sizable portion of ancient deltaic red beds may be of this character, although probably most of them are primary detrital.

When a sediment is brought after burial and emergence into the zone of oxidation (but not of actual surface weathering), its susceptible minerals containing ferrous oxide, such as glauconite, may be oxidized for a depth of 100 feet and more. Such exposed and oxidized sediments are termed post-diagenetic red beds (FIGURE 10).

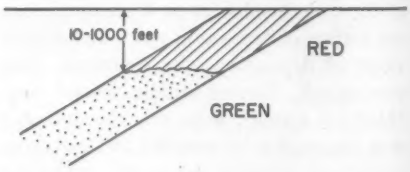

Figure 10. Post-diagenetic red bed formation by subsurface oxidation.

Volumetrically speaking, post-depositional and post-diagenetic red beds are much smaller than the primary ones.

Secondary Red Beds

When a red sediment (not a red soil or regolith) is eroded during a new cycle, its red pigment may form a new red sediment. Naturally, the paleoclimatic significance of such a secondary red bed is nil. Many eolian sediments are of this type, including most of the famous "red sands of the desert" which, in the case of the Northern Sahara red sands, are reworked fluvial Oligocene red sands, and in the Arabian desert are Red Cretaceous sandstones. Many glacial sediments are also red, such as the "pink sand" of Connecticut, derived by glacio-lacustrine reworking of the underlying Triassic; the so-called bloody clays of Bavaria and the red glacial clays of Sweden.

Chemical Red Beds

In all the preceding classes, the red pigment, either actual (primary or secondary) or potential (post-depositional and post-diagenetic) was present as a *solid* within the sediment. In the case of chemical red beds, the red iron oxide pigment is precipitated into the sediment from *solution*. Such precipitation can take place either in a marine or fresh water basin during the formation of a sediment or from circulating solution, intrastratally, after deposition. The vast bulk of chemical red beds are marine and include practically all the iron ore formations of the world, such as the Lake Superior and other Huronian iron ores (Brazil, Russia, Labrador, etc.) and the Silurian Clinton iron ores of the Appalachian region. The marine precipitation mechanism of hematite is somewhat in doubt. Volumetrically, the marine chemical red beds take second place after the primary detrital red bed and, thus, form the second big principal mode of red bed occurrence.

Marine *chemical* red beds are *not* related either to salt or gypsum. The interfingering between evaporites or marine chemical precipitates, and marine *detrital* red beds, has no climatic significanc. On the contrary (in the Permian), as a general rule, when the percentage of salt, gypsum and dolomite goes up, the proportion of red beds goes down (FIGURE 7).

Fresh water red beds form reddish (or rather reddish brown) deposits containing siderite, limonite (including turgite) and similar so-called "bog" iron ores. These are very small volumetrically. Finally, authigenic red beds or rather small red streaks or laminae may form in many subaerially exposed sediments including glacial terraces through the precipitation of limonite from circulating solutions.

Conclusions. Most detrital red beds are formed under warm and moist climatic conditions, possibly in tropical savanna type climates. There is no connection between red color and aridity, the contrary being true. Tectonically red beds are connected mostly with positive movements and frequently are related to strong orogenesis and subsequent peneplanation.

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The concepts presented in this paper summarize the ideas developed by the writer during his work on Red Beds begun in 1929. The following red beds have been investigated petrographically in *some detail* and those marked with the symbol (fw) have also been studied in the field:

Pleistocene and Recent: Glacial deposits of Connecticut (fw); red soils from Burma; red soils and red sediments from Tabasco (fw).

Tertiary: Siwalik series of N. W. India; Sespe of California (fw).

Upper Mesozoic: Various Jurassic red beds from Utah.

Triassic: Newark series from Connecticut (fw), Massachusetts (fw), New Jersey (fw), Pennsylvania (fw); Chinle formation from several Western States (fw); German Triassic.

Permian: Various Permian Red Beds from West Texas (fw), Oklahoma (fw), and Kansas; German Permian.

Pennsylvanian: Fountain formation of Colorado (fw).

Balance of Paleozoic: All from the Appalachian Region; Mississippian Mauch Chunk (fw); Devonian Catskill (fw); Silurian Bloomsburg (fw), and Clinton (fw); Ordovician Juniata (fw); Cambrian Potsdam (fw).

Pre-Cambrian: Algonkian (?) from New York State (fw); Belt series; Lake Superior iron ores.

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SECTION OF BIOLOGY

BARIUM METABOLISM IN HORNETS STUDIED BY MEANS OF RADIOISOTOPES

By V. T. BOWEN*

The experiments reported in this paper were stimulated originally by the discovery, to be reported elsewhere, of hornets of the genera *Vespa* and *Vespula*, as notable accumulators of manganese. Investigation of manganese in these organisms had been prompted by the need for data on other *Hymenoptera*, for comparison to Vinogradov's studies of manganese in ants.[1,2] During discussion of the facts of hornet manganese metabolism with D. F. Waterhouse, he mentioned that, in *Lucilia*, indications were appearing that barium is accumulated much as is copper.[3] This observation, which he has not yet confirmed,[4] prompted selection of barium as the element next to be studied for comparison with manganese.

Since histochemical and microchemical methods for barium are far from satisfactory, this study has been carried on using the radioisotope, barium^{140}, obtained from Oak Ridge, as indicator of the normal pathways of barium through the body. It is not felt that any defense of this procedure is necessary, except to note that the available analyses of plant material for this element[5] indicate its general availability to any organism which can

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absorb it, and that Ballard[6] has provided spectrographic evidence of barium as a normal constituent of two insects.

The distribution of ingested barium^{140} within the organisms was studied both by conventional Geiger-counter examination of dissected organs, and by radioautography. The latter technique employed the method previously described by Evans,[7] and independently developed by several investigators, of mounting histological sections directly on photographic emulsion, which is developed, after suitable time for exposure, with the sections still in place and then mounted under a cover-slip for microscopic examination. It was found that mounting such preparations in a medium of suitable refractive index, glycerine of about 75 per cent concentration having been employed, permitted identification of all tissues and of most cellular constituents, while producing as little interference as possible with the visualization of the underlying photographic grains. Such preparations are extremely revealing and provided the main evidence for the description of the cycle of barium metabolism in hornets. By dividing the series of sections and employing widely differing exposure times, very clear cut pictures could be obtained of localizations differing by 10^4 or more in absolute barium^{140} content.

The barium distribution in the organs of the abdomen of *Vespula* males, at intervals after ingestion of the radioisotope as indicated by an extensive series of radioautographs, is set out in TABLE 1.

Some more precise localizations are notable. The activity in the fat body is evident only where this tissue lies closely apposed to the mid-gut wall. This is true also of the most intense pick-up by the malpighian tubules, which, in fact, are seen to pick up no barium except when lying adjacent to genital tract or mid-gut. In all of the autographs showing high-level radioactivity in the hind-gut, this is seen to lie within the peritrophic membrane-enclosed fecal pellets, indicating direct passage from the mid-gut, rather than absorption, followed by excretion.

TABLE 1

Specimen	1	2	3	4	5	6
Days after feeding	1.8	2.2	3.2	7	14	28
Activity in:						
Mid-gut epithelium	very slight	high	high	high	high	high
Genital tract	definite	definite	definite	nil	nil	nil
Fat Body	nil	strong	strong	slight	nil	nil
Malpighian tubules near gut	very slight	strong	strong	strong	definite	nil
Malpighian tubules near genital tract	nil	definite	definite	definite	nil	nil
Nerve Cord	nil	nil	nil	nil	nil	nil
Hind-gut	very high	high	high	nil	nil	nil

The evidences of this second process are clear-cut in later specimens, but involve greatly lower amounts of barium.

It is possible to discern that the malpighian tubules contain barium in both cells and lumen of the upper portions, but that, distally, only cellular barium is present. The possibility that in the lower portion of the lumen barium is more easily lost during histologic preparation must of course, be kept in mind.

The very high concentrations of barium in the mid-gut epithelium are seen to be undergoing slow redistributions. In the earliest stages, the activity is restricted to the distal border of the cells and shows great variation in intensity, some groups of cells showing many times as much

activity as those lying immediately adjacent. In the later specimens, the activity is seen to spread slowly toward the proximal end of the cells, and the intensity variation to be minimized. Even by 28 days, however, the proximal one-fifth of the cells has not been entered by the stored barium. This discrimination is made possible by the fact that the edge of the localization can be determined to within about 4 micra, in suitable preparations.

On certain specific points, this evidence is supplemented by the counting results. It was shown clearly that the loss of barium by passage to the hind-gut proceeds much more rapidly than does the absorption of barium by the mid-gut epithelium. From 1.5 to 2 days, when virtually no barium is yet in the epithelial cells, the hind-gut already contains as much of the element as is present in both cells and lumen of the mid-gut.

TABLE 2

Very High	10^9 atoms
High	10^8 atoms
Strong	10^7 atoms
Definite	10^6 atoms
Slight	10^5 atoms
Very Slight	probably less than 10^4 atoms

By use of radium D and E, samples prepared and calibrated by the National Bureau of Standards, estimates were made of the total number of atoms of barium^{140} present in the various organs. In TABLE 2 are set out the number of atoms present in the entire organ, studied as a dissection, corresponding to the descriptive terms employed in TABLE 1. This is only an order of magnitude correspondence, due to differences in volume among organs, but is of interest as indicating the extreme sensitivity of the method, as well as the extraordinary delicacy with which the hornet distributes its barium.

In this study, advantage was taken of the fact that barium^{140} decays into lanthanum^{140} which is in turn radioactive and decays into stable cerium^{140}. Since the half-lives of the two processes are respectively 300 hours and 40 hours, any aged sample of barium^{140} is in equilibrium with a definite quantity of lanthanum^{140}, and the decay rate of this equilibrium mixture is that of the first transition. If now this mixture is subjected to a process removing a part of the lanthanum, the decay curve of the remainder will be altered so that for a period of time its activity will increase. On the other hand, if this mixture is subjected to a process removing a part of the barium, the decay curve will be altered so that for a period of time its activity will decrease more rapidly than expected.

Such decay curves made on various dissections of specimens in this series indicate that the radioactivity in the genital tracts of 1.5 day specimens was pure barium^{140}, whereas a specimen taken 4 days after feeding was excreting a mixture somewhat enriched in lanthanum^{140}.

The cyles of barium distribution in male hornets, inferred from the studies briefly summarized above, are diagrammed in FIGURE 1. Detailed exposition of the arguments is not possible here. In the case of the most interesting feature: The existence of two cycles, chemically distinct and operating at different times, the reasoning was based on the following points. Barium appeared in separated form in the genital tract before radioautographs revealed it in any other organ. Although it must have been transported to this point in the hemolymph, no uptake by the malpighian tubules was shown until after this early barium had passed through the genital tract. On the other hand, the later barium, mostly retained by the mid-gut epithelium, when transmitted to the hemolymph, was immedi-

ately absorbed by the adjacent malpighian tubules, and never reached the genital tract. On the diagram, these two points are indicated by the dashed steps, 15 and 16, which do not occur.

Another feature of great interest is the similarity between the treatment of barium by the mid-gut epithelium as inferred here, and the ferritin cycle described for iron in mammalian intestine by Granick.[8] No evidence of control of further barium absorption, by building up of the stored

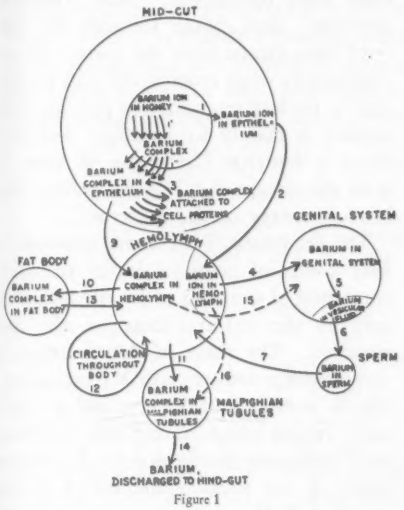

Figure 1

form, has yet been seen, but in other details the similarity is striking. Other intestinal accumulations like that of iron as ferritin have been described for copper in blowflies by Waterhouse[3] and for manganese in hornets by Bowen.[9]

Thus far, no evidence for physiological function of barium has been presented, and none is available from the present study. It is attractive, however, to postulate that the low-level cycle involving the male genital system, may indicate barium as being a physiological element. It is hoped that this problem may be attacked experimentally during the 1949 hornet season.

The studies reported so far involved only males. During the past fall, at Brookhaven National Laboratory, a similar series of experiments has been carried out, on an expanded scale, on both males and queens of the genera *Vespa* and *Vespula*. Although most of the radioautographs have yet to be completed, very definite differences are evident between the two sexes, not merely in relative distribution of barium, but in rate and amount of uptake. This is the more interesting, as no such differences with respect to manganese were noted in the work cited above[9].

The two series of experiments will provide a very solid foundation on which to build a picture of the chemical states and possible function of barium in hornets and perhaps in insects in general.

The major amount of the work described here was performed at Yale University during the author's stay as Research Assistant in Biogeochemistry, supported by the Survey of Contemporary Knowledge in Biogeochemistry of the American Museum of Natural History. A part of this work was presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Zoology at Yale University. As indicated above, the experiments are being continued at the Biology Department of Brookhaven National Laboratory.

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SECTION OF PHYSICS AND CHEMISTRY

INFORMATION OBTAINED FROM THE INTERACTION OF SLOW NEUTRONS WITH MATTER

By JAMES RAINWATER*

In recent years, the physicist has discovered in the slow neutron an excellent tool for the study of the atomic and nuclear properties of matter. It is the purpose of this article to review briefly some of the information which can be obtained from such studies.

Slow neutrons are not produced directly, but are obtained by slowing down the fast neutrons produced by nuclear reactions in, for example, a cyclotron or a chain reacting pile. The neutrons, when produced, have rather high kinetic energies, corresponding to $\sim$ 0.1 to 10 MEV (1 million electron volts = 1.603×10^{-6} ergs). They may be slowed down by elastic "billiard ball" type collisions with light nuclei, such as the hydrogen in paraffin or water. When a beam of fast neutrons impinges on a slab of paraffin, some pass through without effect but some have one or more collisions in the slab with a decrease in kinetic energy at each collision. The energy thus "cascades" to lower values until the kinetic energy of the neutron is of the same order of magnitude as the thermal energies of atoms in the paraffin ($\sim$ 0.04 e.v.). When a neutron has slowed to thermal energies it is apt to gain as easily as lose energy in a collision and comes into thermal equilibrium with the atoms. These "thermal neutrons" then diffuse through the slab until they escape from the surface or are captured by some atom in the slab to produce a nuclear reaction. In paraffin, this capture is mainly by hydrogen and produces a deuteron (hydrogen of mass 2) with the release of 2.23 MEV energy (the binding energy of the deuteron).

The net result of the above processes is that a flux of neutrons leaves the slab, consisting of neutrons of all energies from zero to the initial energy of the fast neutrons. The shape of this spectrum is conveniently broken into a "cascading" region above about 0.3 e.v. and a "thermal" region which corresponds to a Maxwell-Boltzman distribution for the temperature of the paraffin and which centers about $\sim$ 0.04 e.v. for room temperature. The paraffin slab, under such conditions, may be considered as an effective "source" of slow neutrons. Table 1 lists the relations of interest. For neutron energies given in the first row, the second row gives the neutron velocity in meters/sec., and the next gives the inverse (which is important for velocity selector measurements) expressed in microseconds per meter. In a slow neutron velocity selector system, neutrons of different energies are selected by the difference in time required for them to travel a fixed "source-detector distance" of $\sim$ 5 or 6 meters. The fourth

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row shows the time in microseconds for a neutron to travel 5.4 meters. For thermal energies it is seen that the timings are conveniently large (in microsecond units).

The next row gives the wavelength of the neutron. According to our present views based on wave mechanics, all particles have the properties both of a wave motion and of particles. This is true of all particles, such as neutrons, protons, electrons, and photons (electromagnetic energy). The wave length is given by DeBroglie's relation $\lambda = h/p = h/mv$. Here h is Planck's constant and p is the momentum of a particle of mass m and velocity v. The important thing to notice is that λ varies as $1/v$ and is of the same order of magnitude as the spacing of atoms in solids for neutrons of thermal energies. This means that one can expect diffraction and interference effects using slow neutrons just as for X-rays. This will be discussed in greater detail later.

The sixth row gives the mean number of collisions with H atoms required for a neutron to cascade to the given energy starting at 7 MEV. The next row gives the mean free path between collisions at the given energy, and the last row gives the time required to cascade to the given energy. By comparing this time with the time to travel 5.4 meters, it is seen that the cascading time is relatively small and can be neglected.

Table 1

Fundamental Relations Important in the Measurements Described in This Paper

$E \rightarrow$	1 Mev	0.1 Mev	0.01 Mev	1000 ev	100 ev	10 ev	1 ev	0.1 ev	0.01 ev	0.001 ev
V in meters/sec.	1.38×10^{7}	4.38×10^{6}	1.38×10^{6}	437,500	138,400	43,750	13,840	4375	1384	438
Microsec./meter	.0723	.229	.723	2.29	7.23	22.9	723	229	723	2286
Microsec./5.4 meters	.390	1.24	3.90	12.4	39.0	124	390	1235	3900	12,350
λ in A	.0003	.001	.003	.0091	.0286	.0905	.286	.905	2.86	9.05
Collisions required to cascade from 7 Mev	2	4	7	9	11	14	16	18	21	23
Assumed cm m.f.p.	4	1.3	.8	.7	.7	.7	.7	.4	.2	.2
Microsec. time required to cascade	.005	.01	.03	.06	.2	.7	2	4	9	20

Most scientists are very familiar with the type of information obtained from the scattering of X-rays. Each element of volume in a sample scatters with an amplitude proportional to the density of electrons at the point and with a phase which depends on the position of the volume element and on the X-ray wave length and the direction of scattering. For a crystalline material, the directions in which strong scattering occur are those satisfying the Bragg condition $n\lambda = 2\,d \sin\theta$ for the crystal planes. In particular, the scattered amplitude, as a function of scattering direction, is just the Fourier transform of the electron density *vs.* position in the material. Thus, by taking the Fourier transform of the observed scattering amplitude function, one obtains, directly, information concerning the electron density vs. position for the material. This gives most important direct evidence for the size and shape of the electron distribution in atoms. It also shows the distribution of atoms in crystals to give direct information concerning crystal structure and atomic spacings. Recently, these techniques have been applied to the study of the shapes of complex organic molecules. A British group, for example, has now established the atom "map" for penicillium and is attempting to unravel the structure of the red blood cells.

Whereas the scattering of X-rays is by

the electrons in an atom, the scattering of slow neutrons is by the nuclei. Also, where the total scattering of X-rays depends only on the number of electrons in an atom and increases in proportion to the atomic charge number, the magnitude of the nuclear scattering varies in a more or less random manner from element to element depending on specific nuclear interaction effects. Thus, if the magnitude of the interaction is expressed as a "cross section" (cm^2 per atom), the cross section for H is $\sim$ 20 barns (1 barn = 10^{-24} cm^2/atom) while Bi has only 9 barns. Thus, the scattering by neutrons "weights" different atoms quite differently than does the X-ray scattering. For example, it is very hard to locate H atoms by X-rays since they have only one electron for scattering. The extra large scattering cross section of H for neutrons would make it seem that the position of H atoms could be determined easily using neutron scattering, but it turns out that the scattering by H is mainly "incoherent" and it is not as useful as would be expected. However, if the ordinary hydrogen atoms are replaced by deuterium atoms, this trouble is removed and H positions can be determined.

The investigation of slow neutron diffraction has been carried out mainly in conjunction with the chain reacting piles, since an intense flux of slow neutrons is required. Crystal spectrometers for slow neutrons, similar to those for X-rays, have been developed. In general, we may say that the resolution and intensity obtainable with slow neutrons is much poorer than with X-rays, since an X-ray tube is a much more intense source of X-rays than is a pile of slow neutrons. A considerable number of neutron diffraction studies have been started recently and the results of the new technique should become increasingly evident in a few years as the techniques are developed and exploited.

The neutron has no electric charge, but, like the electron, it has a "spin" of $\frac{1}{2}$ unit and an associated magnetic dipole moment. Due to its magnetic moment, there is an interaction with the electron magnetic moment of paramagnetic and ferromagnetic atoms. A beam of slow neutrons passing through a magnetized iron plate is attenuated to a different extent if the neutron spin points in the direction of the magnetic field than if it points in the opposite direction. Thus, a partially polarized beam of slow neutrons may be produced by passing through magnetized iron. The degree of polarization produced depends in a sensitive way on the magnetic domain size and the nearness to magnetic saturation. Such studies have recently given valuable information concerning certain problems of ferromagnetism. The production of polarized slow neutrons has also been used as an analytic method for the precision measurement of the magnetic moment of the neutron which is of great interest to nuclear physics. In a similar manner, the investigation of the transmission of slow neutrons through paramagnetic materials such as MnF_2 promises to give information concerning the effective size of the electron shells responsible for paramagnetism and to show the extent of the local couplings between the different paramagnetic ions.

Neutron diffraction studies also provide information of interest to nuclear physics. The amplitude and *sign* of the scattering of nuclei can be determined from the relative intensity of the Bragg scattering from different crystal planes. This can, in general, be different for different isotopes of a given element and can even be different for a given nucleus depending on how the neutron and nuclear spins combine in the collision. If the scattering amplitude is different for different isotopes, or due to different spin orientation, the intensity of the "coherent" scattering from crystal

planes is reduced and there is an increased incoherent scattering. This is particularly true for hydrogen, where the sign of the scattering is opposite for the two spin orientations, so there is a very large incoherent scattering but very little coherent scattering.

The experiments with which the author has been concerned have involved the use of the Columbia University cyclotron modulated to act as a velocity selector system. The operation may be explained in terms of a specific example. The cyclotron arc (ion source), normally turned off, is turned on for a 4-microsecond interval and then turned off again. This produces a burst of deuterons at the center of the cyclotron which are accelerated and strike the beryllium target a few microseconds later to give a burst of fast neutrons leaving the Be in all directions. A certain fraction of the thermal neutron spectrum reaches a BF_3 proportional counter slow neutron detector situated at the end of a collimated path ending outside the water tank barrier surrounding the cyclotron. Samples to be studied can be placed in the path between the source and detector. The slow neutron transmission (or cross section) of the material is measured by observing the factor by which the counting rate is decreased when the sample is in place. The pulses at the counter will occur whenever a neutron is detected and the time difference between the arc and detection pulses, after suitable corrections, gives the "time of flight" for the neutron to travel the known source detector distance, and thus, from TABLE 1, the neutron energy. By using a system of "gating" circuits, the counts coming in different timing intervals (4 microseconds wide in this example) may be recorded on different registers and, thus, the different energy groups can be separated. The Columbia velocity selector is arranged to measure 16 different energy intervals simultaneously for each of two detector-collimator systems. The geometric arrangement is illustrated in FIGURE 1.

In any spectrometer system the shape of the source spectrum is important. FIGURES 2 and 3 show the intensity *vs.* time of flight of the neutrons from paraffin slabs of two different thicknesses. The relative number of neutrons detected in equal time of flight intervals is shown. An energy scale is given for convenience. (The high energies or high velocities correspond to small timings and vice versa.) The peak in the curves is due to the Max-

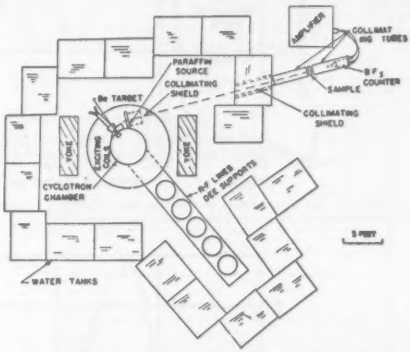

Figure 1. Room plan showing the cyclotron, the water tank shielding the collimating system, and the slow neutron "source," sample, and detector positions.

well-Boltzman distribution for which the solid line gives the theoretical curves. The rise above the solid curve at smaller timings corresponds to the "cascading" neutrons. It is seen that relatively more of the neutrons reach thermal energies with the thick slab.

The relative number of thermal neutrons in the slab at any time after the burst decreases exponentially in time because of losses due to diffusion and capture. This is shown in FIGURE 4 for the same two source slabs. The decay is faster for the thin slab. The observed values agree with the calculated values. The thermal lag must be deducted for measurements below about 0.2 e.v.

The main use of the velocity selector system, however, has been to investigate tion with energy supplies much of the detailed knowledge of the energy levels of

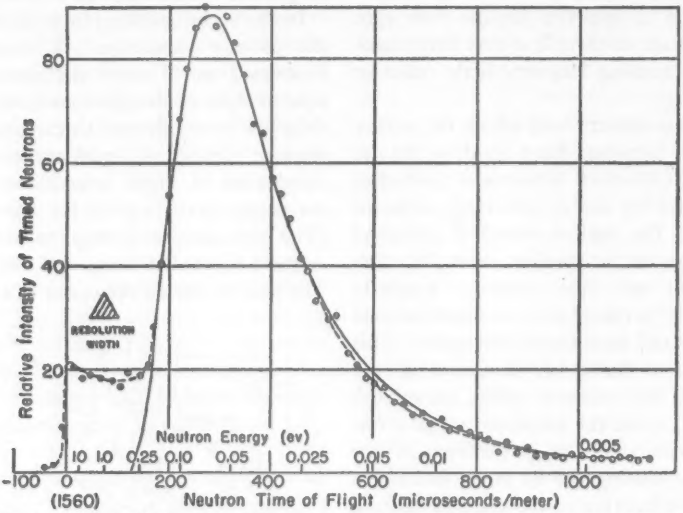

Figure 2. The slow neutron distribution from a "thick" paraffin "source" slab. (6.2 cm thick paraffin in a box of $\frac{1}{4}$" thick plywood.) ○ = experimental curve. — = r^4 theoretical curve for 390°K.

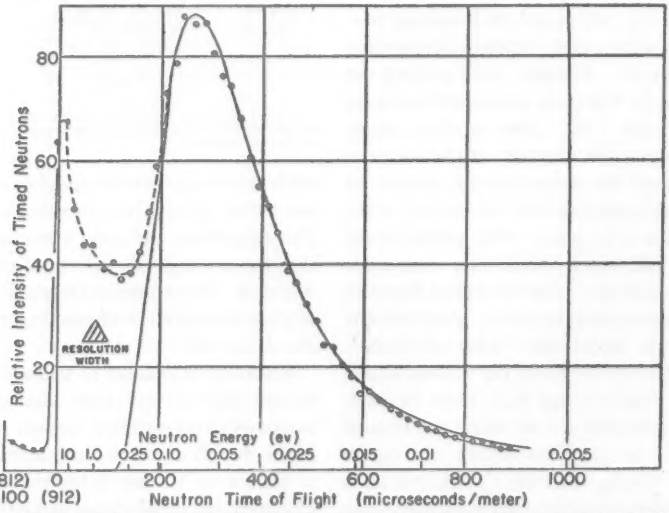

Figure 3. The slow neutron distribution from the "thin" paraffin "source" slab. (2.6 cm thick paraffin in a box of $\frac{1}{4}$" thick plywood.) ○ = experimental curve. — = r^4 theoretical curve for 430°K.

the interaction of slow neutrons with nuclei, since the variation of this interac- these nuclei. Absorption bands are found at low neutron energies which give a

picture of the levels of the compound nucleus in the vicinity of the binding energy of the neutron. The method thus

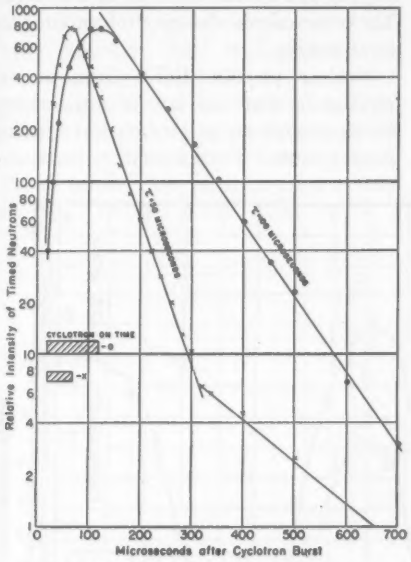

Figure 4. Thermal neutron delayed emission from paraffin "source" slabs. Data taken next to the source with a tiny BF_3 counter. × = 2.6 cm thick paraffin in a box of $\frac{1}{4}$" thick plywood. ○ = 6.2 cm thick paraffin in a box of $\frac{1}{4}$" thick plywood.

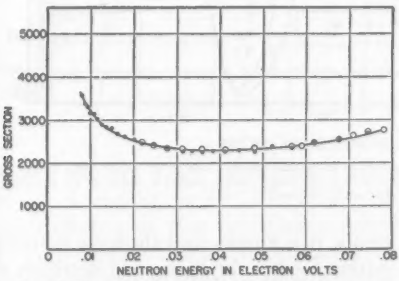

Figure 5. The slow neutron cross section of cadmium in the energy interval 0–0.08 ev. ●, experimental points for the 43.8 mg/cm² sample. ○, experimental points for the 219 mg/cm² sample. The solid line is a theoretical curve using the Breit-Wigner one-level formula with $E_0 = 0.176$ ev, $\Gamma = 0.115$ ev, and $\sigma_0 = 7200$.

permits a microscopic examination of the level structure of the compound nucleus at a region of ~ 8 MEV excitation and provides some of the main experimental evidence concerning level structure.

The Breit-Wigner formula predicts that the absorption should show a resonance maximum at exact resonance and a falling

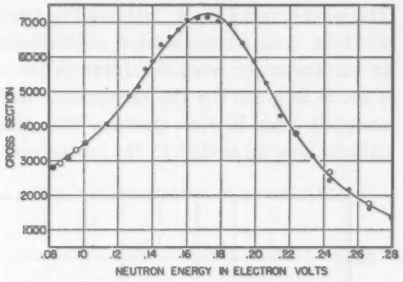

Figure 6. The slow neutron cross section of cadmium in the energy interval from 0.08 ev to 0.28 ev. ●, experimental points for the 43.8 mg/cm² sample. ○, experimental points for the 219 mg/cm² sample. The solid line is a theoretical curve using the Breit-Wigner one-level formula with $E_0 = 0.176$ ev, $\Gamma = 0.115$ ev, and $\sigma_0 = 7200$.

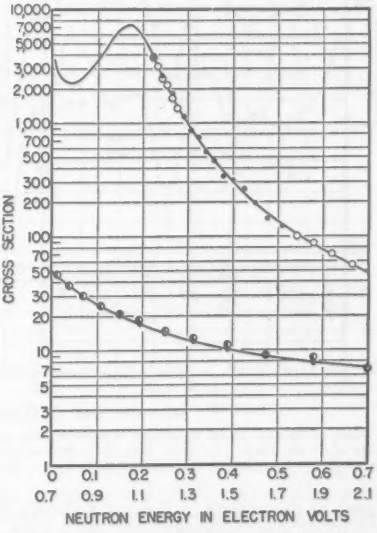

Figure 7. The slow neutron cross section of cadmium in the energy interval from 0.2 ev to 2.1 ev. ●, experimental points for 43.8 mg/cm² sample. ○, experimental points for 219 mg/cm² sample. ◐, experimental points for 4.47 g/cm² sample. ◒, experimental points for 11.03 g/cm² sample. The solid line is a theoretical curve using the Breit-Wigner one-level formula with $E_0 = 0.176$ ev, $\Gamma = 0.115$ ev, and $\sigma_0 = 7200$. A "constant term" of 5.3 has been added to the theoretical curve to account for the scattering cross section.

off away from resonance. It also predicts an additional factor proportional to $1/v$. The most exact check of this formula was made in the case of Cadmium and is shown

in FIGURES 5, 6 and 7. The agreement of the experimental points and the (single) best fitting theoretical curve is shown over the energy range from 0.008 e.v. to 2.1 e.v. The level is at 0.176 e.v. and has a width of 0.115 e.v. with a cross section of 7200 barns at maximum for normal Cadmium (or ~ 8 times as much for the responsible Cd^{113} isotope). At higher energies the resonances show up as dips in the transmission of elements. The results for Cadmium permit the calculation of the mean life of the compound nucleus for the emission of a γ ray and for the emission of a neutron. The other curves also give information on level density.

Nuclear physics differs from atomic physics in that the law of force acting between nucleons to give nuclear binding is not known. From a number of measure-

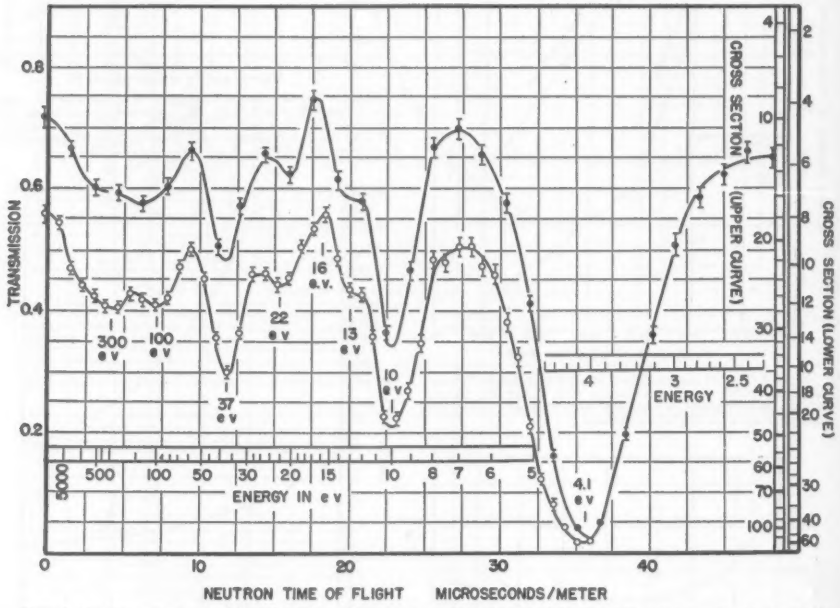

Figure 8. The slow neutron transmission of tantalum. The upper curve shows the transmission for a 9.98 g/cm² sample with a resolution width of 3.6 μsec./meter. The lower curve shows the transmission for a 22.44 g/cm² sample with a resolution width of 1.8 μsec./meter. The use of the thicker sample with higher resolution increases the detail that can be obtained.

curve of the sample. FIGURE 8 shows the results for two thicknesses of tantalum showing levels at 4.1, 10, 13, 22, 37, and many near 100 to 300 e.v. neutron energy. FIGURE 9 gives the results for Cobalt showing the $1/v$ slope at low energies and the strong resonance at 115 e.v. This is shown better in FIGURE 10 which also shows a level near 10,000 e.v. Such curves have now been obtained for a large number

ments, it is known that the force is strong within $\sim 2 \times 10^{-13}$ cm. and decreases to zero very rapidly at larger distances. The neutron-proton interaction, or deuteron problem, represents the fundamental two body interaction in nuclear physics analagous to the H atom in atomic physics. For any given assumption concerning the force law, the two body problem can be reduced to a one body problem and solved

exactly. Thus, all information concerning the neutron-proton interaction is of utmost interest to nuclear physics. The neutron and proton are known to combine to form a stable system (deuteron) of 2.23 MEV binding. This is a triplet state corresponding to parallel spins. Assuming any given range for the nuclear forces and knowing the binding energy of the deuteron, it is possible to calculate exactly the (triplet) slow neutron-proton cross section. The predicted result is $\sim$ 4 barns compared to the experimental value of (20.36 $\pm$ 0.10) barns. The reason for this difference is that the nuclear forces are spin dependent and the interaction is only about half as large for opposite spins in the singlet interaction. This turns out to not quite give binding for the singlet interaction but to give a near resonance cross section of $\sim$ 70 barns. Weighting the triplet interaction $\frac{3}{4}$ and the singlet interaction $\frac{1}{4}$ gives the observed value. The sign of the scattered amplitude is opposite in the two cases, as is shown by scattering from crystals containing hydrogen and by the ortho-para hydrogen experiment. H_2 molecules can exist as ortho-hydrogen in which the two proton spins are parallel, or as para-hydrogen in which the proton spins are opposed. Interference effects in the scattering of very slow neutrons by H_2 gas at $\sim$ 20°K result in a cross section of $\sim$ 4 barns for para-hydrogen and $\sim$ 125 barns for ortho-hydrogen. In terms of the binding energy of the deuteron and the "free proton cross section" (20.36), it is possible to calculate the expected para-hydrogen cross section for any chosen value of the range of the nuclear forces and this provides the most precise evaluation of the range of the neutron proton force.

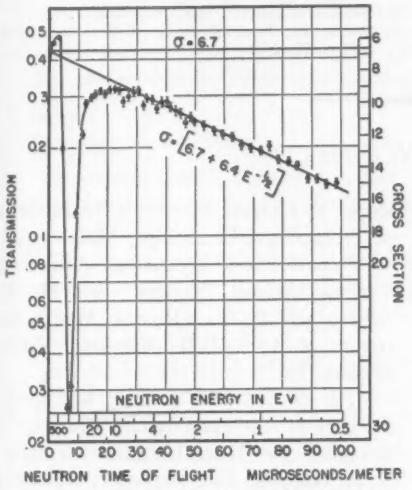

Figure 9. The slow neutron transmission of 12.4 g/cm² of cobalt. This figure shows a strong dip near 100 ev and another small dip at zero time of flight.

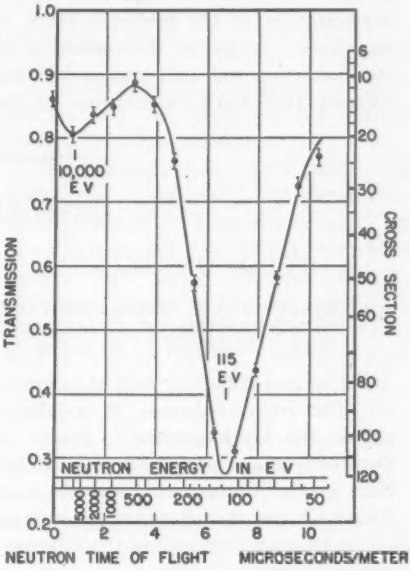

Figure 10. The slow neutron transmission of 1.06 g/cm² of cobalt. This curve was taken by using a thinner sample and maximum resolution.

Recently, we have begun an experiment to measure the neutron-electron (nonmagnetic) interaction by an indirect method involving a very precise measurement of

the slow neutron cross-section *vs.* energy of liquid lead and bismuth. This interaction is of great importance since it gives direct evidence concerning the meson theory of nuclear forces. On this picture, a neutron is considered to be a "simple" neutron part of the time and a proton and negative meson part of the time. The electron interacts with the (virtual) proton-negative meson system to give a scattering. The observed magnitude of the interaction is of the predicted order of magnitude. A precise determination of the interaction will help choose between different alternative formulations of the theory. The other data which must be fitted by an adequate meson theory of nuclear forces include the binding energy of the deuteron, the magnetic dipole moments of the neutron, proton, and deuteron, the ortho-para hydrogen scattering proton-proton scattering, and the electric quadrupole moment of the deuteron.

References

1. Rainwater, Havens, Wu, Dunning & Meaker. 1947. Phys. Rev. **71**: 65, 165, 174. 1948. Phys. Rev. **73**: 733, 963.
2. Wollan & Shull. 1948. Nucleonics.
3. Goldsmith, Isser & Feld. 1947. Rev. Mod. Phys. **19**: 259.

CONFERENCE HELD

SECTION OF BIOLOGY

CONFERENCE ON "THE GROUND SUBSTANCE OF THE MESENCHYME AND HYALURONIDASE": DECEMBER 3 AND 4, 1948

The section of Biology held a Conference on "The Ground Substance of the Mesenchyme and Hyaluronidase." Doctor F. Duran-Reynals, Yale School of Medicine, New Haven, Connecticut, was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, December 3

Morning Session. Fundamental Data on the Ground Substance of the Mesenchyme.

Chairman: K. Meyer

"The Mucopolysaccharides of the Interfibrillar Substance of the Mesenchyme" by K. Meyer, College of Physicians and Surgeons, Columbia University, New York N. Y.

"A Study of Certain Connective Tissue Constituents with the Electron Microscope" by J. Gross, Massachusetts Institute of Technology, Cambridge, Mass.

"Preparation of Hyaluronic Acid from Various Animal Sources" by H. E. Alburn and E. C. Williams, Wyeth Institute of Applied Biochemistry, Philadelphia, Pa.

"The Distribution of Acid Mucopolysaccharides in Mammalian Tissues, as Revealed by Histochemical Methods" by H. Bunting, Yale University School of Medicine, New Haven, Conn.

"Histological Studies of the Reactions of Cells and Intercellular Substances of Loose Connective Tissue to the Spreading Factor of Testicular Extract" by S. H. Bensley, University of Toronto School of Medicine, Toronto, Canada.

"Solubility Properties of Some Components of the Ground Substance and the Relation to Intravital Staining of Connective Tissue" by H. R. Catchpole, University of Illinois College of Medicine, Chicago, Ill.

"Physiological Conditions Existing in

Connective Tissue" by P. McMaster, Rockefeller Institute for Medical Research, New York, N. Y.

"The Cutaneous Mucopolysaccharides in Localized (Pretibial) Myxedema" by E. M. Watson and R. H. Pearce, Faculty of Medicine, University of Western Ontario, London, Canada.

"Some Studies on the Cutaneous Mucopolysaccharide of the Sex Skin of *Macaca mulatta*" by G. Van Wagenen, H. Bunting, and F. Duran-Reynals, Yale University School of Medicine, New Haven, Conn.

Afternoon Session. The Permeability of the Ground Substance in Infection and Other Conditions.

Chairman: D. H. Sprunt.

"The *in vitro* Action of Hyaluronidase" by A. Dorfman, University of Chicago School of Medicine, Chicago, Ill.

"The Action of Hyaluronidase on Hyaluronic Acid" by K. Meyer, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"*In vitro* Studies with Hyaluronidase" by Sibylle Tolksdorf, James W. Cassidy, Marion H. McCready, and D. Roy McCullagh, Schering Corporation, Bloomfield, New Jersey.

"Spreading Factors and Their Mechanism of Action" by O. M. Hechter, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

"The Action of Hyaluronidase on Extracellular Structures" by R. Chambers and B. W. Zweifach, New York University and Cornell University Medical College, New York, N. Y.

"The Ground Substance in Infection" by D. H. Sprunt, University of Tennessee, Memphis, Tenn.

"The Function of Hyaluronidase in Hemolytic Infection" by B. Sallman and J. M. Birkeland, Ohio State University, Columbus, Ohio.

"The Production of Hyaluronic Acid and Hyaluronidase by Some Strains of Group A Streptococci" by R. M. Pike, Southwestern Medical School, Dallas, Texas. (Read by title)

Saturday, December 4

Morning Session. The Permeability of the Ground Substance in Infection and Other Conditions (Concluded).

Chairman: M. Lurie

"Mechanisms Affecting Spread in Tuberculosis" by M. Lurie, Henry Phipps Institute, Philadelphia, Pa.

"The Suppression of Experimental Rickettsial Infection by Anti-organ Sera in the Presence of Testicular Extract" by L. Anigstein and D. M. Whitney, University of Texas, Medical Branch, Galveston, Texas. (Read by title)

"Inhibition Effect of Blood Serum on Hyaluronidase" by A. Dorfman, University of Chicago School of Medicine, Chicago, Ill.

"Inhibition of Hyaluronidase by Serum" by Z. Hadidian, Tufts Medical College, Boston, Mass.

"Hyaluronic Acid—Hyaluronidase and the Rheumatic Diseases" by C. Ragan and K. Meyer, College of Physicians and Surgeons, Columbia University and Presbyterian Hospital, New York, N. Y.

"Inhibition of Streptococcal Hyaluronidase by Human Sera" by J. G. Friou and R. W. Quinn, Yale University School of Medicine, New Haven, Conn.

"Mucolytic Enzymes and Invasion by Carcinomas" by W. L. Simpson, Detroit Institute of Cancer Research, Detroit, Mich.

"Use of the Streptococcal Decapsulation Test as a Measure of Thermolabile Hyaluronidase Inhibitor in Serum" by J. K. Fulton, S. Marcus, and W. D. Robinson,

University Hospital, University of Michigan, Ann Arbor, Mich.

Afternoon Session. Pharmacology and Therapeutic Applications of Hyaluronidase. Chairman: J. Seifter.

"Studies on Pharmacology and Toxicology of Hyaluronidase" by J. Seifter and J. J. Christian, Wyeth Institute of Applied Biochemistry, Philadelphia, Pa.

"The Influence of Hyaluronidase on the Course of Certain Bacterial and Viral Infections" by G. H. Warren, Wyeth Institute of Applied Biochemistry, Philadelphia, Pa.

"The Use of Hyaluronidase with Local Anesthetic Agents in Surgery and Dentistry" by C. H. Kirby, J. P. Looby and J. E. Ekenhoff, School of Medicine and Dentistry, University of Pennsylvania, Philadelphia, Pa.

"The Clinical Use of Hyaluronidase in Hypodermoclysis and Urography" by C. L. Burket and P. Gyorgy, Altoona, Pa., and University of Pennsylavania, Philadelphia, Pa.

"Further Observations on the Value of Hyaluronidase in the Treatment of Human Infertility" by R. Kurzrock, New York, N. Y.

"A Statistical Analysis of the Interrelationships of Spermatozoa Count, Hyaluronidase, and Fertilization" by B. Sallman and J. M. Birkeland, Ohio State University and the Ohio Agricultural Experiment Station, Columbus, Ohio.

"Evidence Contra-indicating the Value of Hyaluronidase in Therapy of Human Male Infertility" by M. C. Chang and N. T. Werthessen, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

REPORT OF THE ANNUAL MEETING

December 15, 1948

The 131st Annual Meeting of the Academy, for the election of Officers and Fellows, the presentation of reports, and the transaction of other business was held at the Hotel Astor on the evening of Wednesday, December, 15, 1948.

The first order of business was devoted to the reports of the Officers and Committees of the Academys.

REPORTS OF OFFICERS AND COMMITTEES

Report of the Recording Secretary. This year, particularly, it is a great pleasure to report on the progress made in our activities, the status of our membership, as well as on the plans for the future development of the Academy.

The scope of this progress is noteworthy because of the wide range of the subjects dealt with at the meetings, the high quality of the papers presented and the scientific calibre of the speakers and discussants.

We wish to express our sincere appreciation for the efficiency and generous cooperation of the chairmen of the Sections, the various chairmen and speakers at the eight conferences and the forty-three stated Sectional meetings held during the past year. One hundred and seventy-seven

important scientific papers were read and discussed at these meetings.

At the Annual Meeting, excellent addresses were delivered by President Harden F. Taylor, Mr. George A. Sloan and Doctor W. Albert Noyes, Jr., under the general title "New York as the Crossroads in the World of Science."

Two lectures were also given before Special Meetings of the Academy. The first by H. R. H. Prince Peter of Greece on "Tibetan, Toda and Tiya Polyandry;" the second by Doctor Jean Pasteels of Brussels, Belgium on "The Evolution of Nucleic Acid in the Germinal Cycle of *Ascaris megalocephala* as Studied by Cytochemical Methods."

Our special appreciation is extended to Doctors M. L. Tainter, Raymond N. Bieter and Hans Molitor for organizing and conducting the conference on "Newer Synthetic Analgesics" and for obtaining grants-in-aid to make possible the early publication of the proceedings which have appeared under this title.

Thanks are also due to Doctor Perrin H. Long for his successful management of the conference on "Antibiotics Derived from *Bacillus polymyxa*" and to Doctor M. J. Kopac who developed the conference on "The Mechanisms of Cell Division."

The conference on "Methodology and Techniques for the Study of Animal Societies" was sponsored jointly by The New York Academy of Sciences and The New York Zoological Society, in connection with which we wish to particularly thank Doctor J. P. Scott and the Committee for the Study of Animal Societies under Natural Conditions for the splendid arrangement of the program for this meeting.

The Section of Biology also sponsored the conference on "Aureomycin—A New Antibiotic" for which we acknowledge the wholehearted efforts of the late Doctor Y. SubbaRow and extend thanks to Doctor A. R. Dochez, the Chairman of this conference.

The Section of Oceanography and Meteorology sponsored the conference on "Ocean Surface Waves." Doctor Bernhard Haurwitz is most deservedly to be thanked for organizing the conference and for his success in arranging for a grant-in-aid toward the prime publication costs of the proceedings.

The conference on "Human Engineering" was recognized as of outstanding importance. This meeting was held under the auspices of the Section of Psychology and was ably administered by Doctor Lawrence Edwin Abt.

The twenty-fifth Anniversary of the origin of the Debye-Hückel theory was celebrated by the holding of the conference on "Molecular Interaction," with Doctor Peter Debye as Presiding Chairman. Doctor Raymond M. Fuoss deserves exceptional credit and thanks as the Organizing Chairman.

A Division of Mycology has been established under the Section of Biology in response to the wide interest which has arisen, during the past few years, in this field. The organization of the Division has been carried out through the efforts of Doctor Frederick Reiss.

The future development of the Academy centers around the acquisition of a new home where these conferences and evening meetings may be suitably accommodated, with provision for the efficient administration of the Academy's functions.

The Council of the Academy has announced a Building and Sustaining Fund Campaign for a goal of $1,000,000. Half of this sum will be used to purchase a building, attractive and adequate for our purposes. The remainder will be used as a Sustaining Fund to maintain the new home and expand the Academy's activities.

These plans are clearly presented in the brochure entitled "The New York Academy of Sciences—Past, Present and Future" which has been circulated to the entire membership.

The membership has been assigned a quota of $250,000. One thousand transfers from the Annual Classes to Life Membership, at the established fee of $200 each, will produce the sum of $200,000. Payments of this fee may be made over a period of the next two years, if desired.

It is obvious that to accomplish our purpose the unified support and hearty cooperation of all our Members are indispensable. The Recording Secretary earnestly urges that each individual Member will consider it his responsibility to aid in every possible way to achieve its goal.

During the year 1948, there have been added to our rolls, two Life Members, 29 Sustaining Members, 668 Annual Active Members and 40 Student Members, of which 718 are now in good standing and 21 await qualification through payment of dues. Thus, a total of 739 new Members were added during the year. Five Annual Members were transferred to Life Membership by payment of the Life Membership fee. 352 transfers and 18 reinstatements were also effected. Of the 352 transfers, 336 Associate Members transferred to the Active Membership Class.

The Academy has lost by death 4 Honorary Life Members, 2 Sustaining Members and 13 Annual Active Members.

474 resignations were accepted, 240 names were dropped for non-payment of dues and 3 for not having qualified for membership. This is but a moderate loss considering the increase in dues at the beginning of this calendar year.

The record now stands with a net gain of 21 Members. There are, at present, upon the rolls of the Academy 4030 Members, of whom 547 are Fellows, classified as follows: 1 Benefactor, 1 Patron, 45 Honorary Life Members, 105 Active Life Members, 150 Annual Sustaining Members, 3,637 Annual Active Members, 91 Annual Student Members.

Report of the Corresponding Secretary. Record is made with regret that, due to the death of four Honorary Life Members, the number upon the rolls of the Academy was reduced from 49 to 45 during the past year.

Report of the Editor. Since the date of the last Annual Meeting, December 17, 1947, The New York Academy of Sciences issued 11 ANNALS monographs, comprising a total of 1416 pages. Included in these are 102 papers by 169 authors. The TRANSACTIONS (308 pages) bring the total pagination up to 1724.

The list of the publications issued is, as follows:

ANNALS

Volume 49, Article 2, "*Chromatography*" (14 papers), by H. G. Cassidy, N. Applezweig, S. Claesson, V. R. Deitz, B. J. Mair, A. J. P. Martin, S. Moore, R. L. Peck, W. A. Schroeder, L. Shedlovsky, W. H. Stein, H. C. Thomas, and L. Zechmeister. Pages 141–326. Published February 10, 1948.

Volume 49, Article 3, "*Bioluminescence*" (5 papers), by E. N. Harvey, R. S. Anderson, J. B. Buck, A. M. Chase, H. Eyring, and F. H. Johnson. Pages 327–482. Published April 15, 1948.

Volume 49, Article 4, "*Hemorrhage*" (16 papers) by G. Shwartzman, C. H. Best, R. Chambers, C. S. Davidson, J. H. Ferguson, R. F. Furchgott, I. E. Gerber, M. I. Gregersen, P. György, R. L. Haden, C. Hyman, L. B. Jaques, P. Klemperer, R. E. Lee, C. N. H. Long, D. W. Richards Jr., R. H. Schneider, E. Shorr, H. J. Tagnon, S. A. Thayer, L. C. Underwood, D. C. Van Slyke, A. E. Wilhelmi, and B. W. Zweifach. Pages 483–660. Published May 11, 1948.

Volume 49, Article 5, "*Recent Studies in the Mechanisms of Embryonic Development*" (9 papers) by E. J. Boell, D. P. Costello, S. R. Detwiler, G. Fankhauser, J. Holtfreter, J. S. Nicholas, S. M. Rose, D. Rudnick, and L. S. Stone. Pages 661–866. Published September 24, 1948.

Volume 49, Article 6, "*Current Trends in Clinical Psy-*

chology" (6 papers), by A. W. Combs, H. E. Durkin, M. L. Hutt, J. G. Miller, J. L. Moreno, and F. C. Thorne. Pages 867–928. Published October 8, 1948.

Volume 50, Article 1, "*A Biochemical Hypothesis of the Genesis of Cancer*" (1 paper), by L. A. Pinck. Pages 1–18. Published February 6, 1948.

Volume 50, Article 2, "*The Chemotherapy of Filariasis*" (15 papers), by L. L. Ashburn, F. C. Bartter, R. N. Bieter, F. J. Brady, L. M. Brancone, T. Brey, L. G. S. Brooker, H. W. Brown, E. Bueding, T. A. Burch, M. C. Clark, L. T. Coggeshall, D. B. Cowie, A. C. Cuckler, J. T. Culbertson, R. W. Cunningham, E. M. Cranston, J. J. Denton, S. Halliday, B. K. Harned, R. I. Hewitt, S. Kushner, J. T. Litchfield, Jr., W. L. McEwen, T. H. Maren, J. Oliver-Gonzalez, G. F. Otto, L. Peters, H. M. Rose, D. Santiago-Stevenson, H. W. Stewart, Y. SubbaRow, R. J. Turner, R. E. Vessey, W. S. Wallace, D. E. White, H. N. Wright, and N. N. Yuda. Pages 19–170. Published May 25, 1948.

Volume 50, Article 3, "*The Inhibition of Malarial Relapses by Toxoid of Clostridium Tetani*" (1 paper), by E. Y. Garcia. Pages 171–186. Published June 7, 1948.

Volume 50, Article 4, "*Teleological Mechanisms*" (5 papers), by L. K. Frank, G. E. Hutchinson, W. K. Livingston, W. S. McCulloch, and N. Wiener. Pages 187–278. Published October 13, 1948.

Volume 51, Article 1, "*Newer Synthetic Analgesics*" (16 papers), by M. L. Tainter, H. J. Anslinger, R. C. Batterman, R. N. Bieter, S. Bogolub, K. K. Chen, N. B. Eddy, L. Glassman, B. B. Hershenson, S. A. Hirsh, R. W. Houde, H. Isbell, E. H. Jenney, J. S. LaDue, L. C. Miller, E. E. Nelson, C. C. Pfeiffer, L. H. Rasmussen, E. A. Rovenstine, M. H. Seevers, L. F. Small, R. R. Sonnenschein, and F. F. Yonkman. Pages 1–174. Published November 1, 1948.

Volume 51, Article 2, "*Aureomycin—A New Antibiotic*" (16 papers), by B. M. Duggar, L. Anigstein, J. Beninson, E. A. Bliss, A. E. Braley, R. L. Brickhouse, M. L. Bryer, C. A. Chandler, M. C. Clark, H. S. Collins, R. Cosgrove, H. R. Cox, R. W. Cunningham, A. C. Dornbush, H. F. Dowling, M. Finland, B. K. Harned, C. H. Hine, L. M. Hill, E. H. Lennette, M. H. Lepper, P. A. Little, M. A. Logan, P. H. Long, W. J. McCauley, G. Meikeljohn, T. F. Paine, Jr., E. J. Pelcak, C. W. Price, A. Prigot, W. A. Randall, M. Sanders, E. B. Schoenbach, E. Stokey, Y. SubbaRow, L. K. Sweet, H. M. Thelen, R. E. Vessey, H. Welch, D. M. Whitney, S. C. Wong, L. T. Wright, and N. N. Yuda. Pages 175–342. Published November 30, 1948.

In addition to the articles published during the year, the following are now in press and will be published during the next few months:

Volume 50, Article 5, "*Thyroid Function as Disclosed by Newer Methods of Study*" (12 papers), by J. H. Means *et al.*

Volume 50, Article 6, "*The Adrenal Cortex*" (11 papers), by R. Gaunt *et al.*

Volume 51, Article 3, "*Ocean Surface Waves*" (15 papers), by A. J. Abdullah *et al.*

Volume 51, Article 4, "*Molecular Interaction*" (19 papers), by R. M. Fuoss *et al.*

TRANSACTIONS

Series II, Volume 10, Numbers 1–8, consisting of 308 pages, was completed, printed and distributed each month from November, 1947, to June, 1948, inclusive.

SCIENTIFIC SURVEY OF PORTO RICO

Volume 17, Part 1 of the series, "*The Pelecypoda of Porto Rico and the Virgin Islands*," by Richard A. McLean, is now in press and will be published during the coming year.

Volume 18, Parts 3 and 4, "*Porto Rican Prehistory (I): Introduction; Excavations in the West and North*," and "*Porto Rican Prehistory (II): Excavations in the Interior, South and East; Chronological Implications*," by Irving Rouse, is in the Editor's hands and is being prepared for publication.

During the year, the Academy has distributed 86,989 separate publications and 10,978 complete volumes of the various published series, as follows:

Separate Numbers (including authors' reprints)—*Annals*, 48,254; *Memoirs*, 3; *Special Publications*, 6,600; *Scientific Survey of Porto Rico*, 428; *Transactions*, 29,337; *Bulletins*, 2,367.

Volumes—*Special Publications*, 1,827; *Transactions*, 4,180; *Bulletins*, 4,971.

The Academy has received, from exchange institutions, 2,113 separate publications, which have been duly turned over to the Library of The American Museum of Natural History, in accordance with the purchase agreement between the two institutions. All publications included in the Annals and Transactions, as soon as they are ready for distribution,

are sent to the exchange institutions throughout the world.

The total sales value of publications, distributed gratis to the Members, authors, grantors, reviewers, and exchange institutions is $50,603.70.

Report of the Treasurer. During the fiscal year, ending November 30, 1948, greater financial progress has been made by the Academy than ever before.

The income from all sources totaled $92,564.55, of which $3,245.97 has been credited to capital funds, leaving a remainder of $89,318.58, as income for general operating purposes.

The total operating expenses amounted to $98,019.62, which is $8,794.04 in excess of income. However, the unexpended balance of $11,367.60, reported as surplus on November 30, 1947, included $10,000., which covered three grants-in-aid of the publication costs of Special Publications, Volume IV, entitled "The Biology of Melanomas," which appeared early in January, 1948.

It is most gratifying to report that through the member's ready support of the increase in annual dues and the addition of 739 new members, the income from this source amounted to $38,070.00, which is $20,405.23 above that for the previous year.

The income from sales of publications has continued to increase and is $1,967.65 above that received during the fiscal year, 1947.

It should be noted that more than two-thirds of the total of operating costs were devoted to publication costs (i.e., $66,551.70).

The book value of the Academy's investments and cash on hand, as of November 30, 1948, now amounts to $98,921.32, as shown on the balance sheet. There is a net surplus of $2,666.56, above the total of the endowment funds, at the end of the fiscal year. The interest on investments amounted to $4,906.33, representing a yield of 5.2%. Through sales of certain stocks a net capital gain of $2,281.17 was produced.

The ability of the Academy to render the service of which it is capable depends greatly upon a steadily increasing financial status.

Due to careful planning by the Council, with prudent use of the income of the Academy, maximum results have been obtained from the funds available in the production and distribution of publications, increase of membership, and in number and quality of the meetings including an exceptional series of conferences held; but, what has been done is only preliminary to the task yet to be accomplished.

That this has been a year of signal progress is also evidenced by the substantial beginning which has been made on the realization of our long-cherished hopes and plans to secure a permanent home for the Academy with space and facilities suitable for the expansion of its activities until it shall become a center for Science in New York City.

A drive has been developed to obtain one million dollars, $500,000. of which will be devoted to the purchase, equipment, and furnishing of a building. The remaining $500,000., is the amount estimated as necessary to cover the maintenance and upkeep of the building, as well as the expansion of our activities, which would result from improved facilities made possible by the new location.

We are asking our membership to give this enterprise a substantial impetus at the beginning by becoming Life Members, paying the requisite fee of $200., each. If one thousand members respond in this way, $200,000. would be obtained. It is

THE NEW YORK ACADEMY OF SCIENCES

BALANCE SHEET

November 30, 1948

ASSETS

Cash in Chase National Bank		
General Account	$314.48	
Special Funds Account	1,004.18	
Building and Sustaining Fund	1,690.83	$3,009.49
Investments—at cost		72,952.88
Advances for Bldg. Fund Campaign		22,958.95
Total Assets		$98,921.32
Capital Funds		
General Endowments		$83,645.62
Special Endowments		10,918.31
Bldg. & Sustaining Fund		1,690.83
Total Capital Funds		$96,254.76
Surplus		
Unexpended balance 11/31/47	$11,367.60	
Less: Excess of expenses over income availed of for year	8,701.04	
Surplus Balance 11/30/48		$2,666.56
Total Capital & Surplus		$98,921.32

THE NEW YORK ACADEMY OF SCIENCES

STATEMENT OF INCOME AND EXPENSES

Year Ended November 30, 1948

Income—All Sources		
Membership dues		$38,070.00
Sales of Academy Publications		27,115.29
Contributions & grants for publications and conferences		15,827.16
Sales of dinner tickets		1,546.25
Library exchange, Am. Museum of Nat. Hist.		100.00
Investment income		4,378.71
Net Capital Gains on security sales		2,281.17
Other income, credited to Capital funds		3,245.97
Total Income—All Sources		$92,564.55
Operating Expenses		
Publication costs		66,551.70
General administrative expenses		23,582.69
Equipment purchases		952.43
Meeting and conference expenses		5,580.25
Membership expansion costs		622.99
A. Cressy Morrison prizes		700.00
Preliminary campaign survey—balance		29.56
Total Operating Expenses		$98,019.62
Deduct:		
Total Income—All Sources (as above)	$92,564.55	
Less: Income credited to capital (as above)	3,245.97	
Balance-Income for General Purposes		$89,318.58
Excess of expenses over income availed of in year ending November 30, 1948		$8,701.04

also hoped that some of our members may be willing to contribute larger gifts, ranging from $1000. to $5,000. and more, if possible, that this phase of the goal may be attained more rapidly.

The remaining 3,000 Members, namely, three-fourths of our membership, should contribute sums totaling $50,000., thus bringing the entire contribution of the membership to $250,000. or more, as a nucleus on which we may base our requests for larger contributions from outside sources, in order to obtain the remaining $750,000.

We wish to acknowledge with gratitude and appreciation, on behalf of the Academy, seventeen donations or grants totaling $15,827.16, received during 1948, to aid in defraying both conference and publication expenses, as follows: Lederle Laboratories Division, American Cyanamid Company, $10,419.66; Ciba Pharmaceutical Products, Inc., $1,200; Donner Foundation, $500; Morris and Cuna Fogelman Foundation, $500; Hoffman-LaRoche, $400; Merck & Company, $400; E. R. Squibb & Sons, $400; Sterling Winthrop Inc., $400; The Upjohn Company, $400; Smith, Kline & French Laboratories, $300; Abbott Laboratories, $250; Eli Lilly Laboratories, $200; J. D. Searle & Co., $100; Burroughs-Wellcome Laboratories, $150; Sharpe & Dohme Co., $100; Mr. M. Dole, on behalf of Doctor Grinnell Jones's students, $57.50; J. S. Baker Chemical Co., $50. Our thanks are due also to the generous contributors and grantors who have donated a total of $1,690.83 to the Building and Sustaining Fund and whose timely grants have been made in advance of its official start; and to all others, specifically the membership, who have made our progress possible on a sound financial basis during this past fiscal year.

By order of the Council, the books of account have been checked and certified by a professional firm of auditors.

The financial report of the Academy has been approved by the Finance Committee, as provided in the By-Laws and by the Executive Committee, acting on behalf of the Council.

The property of the Academy was verified by the auditors and the Treasurer's Report examined by these Committees, as of December 13, 1948.

AWARDS OF PRIZES

Two prize competitions were announced for the year 1948: (I) Two prizes of $200.00 each in The A. Cressy Morrison Prize Competition in Natural Science and (II) one prize of $200.00 in The George Frederick Kunz Prize Competition in Geology and Mineralogy.

(I) For the A. Cressy Morrison Prizes in Natural Science of $200.00 each, twelve papers were offered, all of high quality. After careful consideration and consultation with experts in the fields represented, the Committee made the following awards:

(1) A prize of $200.00 to the paper entitled "Effect of Concentration on the Viscosity of Dilute Solutions", by Robert Simha of the National Bureau of Standards, Washington, D. C.*

(2) A prize of $200.00 to the paper entitled "The Relation of the Adrenal Cortex to the Structure and Phagocytic Activity of the Macrophagic System," by Albert S. Gordon and Grace F. Katsh, De-

* For abstracts of this and other prize papers, see pp. 96-98 of this number of TRANSACTIONS.

partment of Biology, Washington Square College of Arts and Sciences, New York University, New York City.

(3) The paper entitled "Porto Rican Prehistory," by Irving Rouse, Associate Curator, Peabody Museum of Natural History, Yale University, New Haven, Connecticut, was so obviously on a par with the other two papers, that Mr. Morrison has generously come to the aid of the Committee and has donated a third prize of $200.00 as a special award to this paper.

(II) The George Frederick Kunz Prize in Geology and Mineralogy of $200.00 was awarded to the paper entitled "Drainage Evolution in the Appalachians of Pennsylvania," by Henry D. Thompson, Professor of Geology and Head of the Department of Geology and Geography, Hunter College, New York City.

The Committee is pleased to announce that Mr. Morrison has generously renewed his offer of two prizes of $200.00 each, for the two most outstanding papers in a field of natural science covered by the Academy and its Affiliated Societies, to be competed for during the year 1949. Announcement of these awards will be made at the Annual Meeting of the Academy to be held in December, 1949.

ELECTION OF FELLOWS AND HONORARY LIFE MEMBERS

The following Members were elected to Fellowship:

Lawrence Edwin Abt, Ph.D.
A. Elizabeth Adams, Ph.D.
Harry G. Albaum, Ph.D.
A. Ansbacher, D.Sc.
Lawrence Atkin, Ph.D.
James W. Atz, A.B.
Donald Wyckoff Baker, Ph.D.
Robert W. Bates, Ph.D.
Stanley D. Beard, Ph.B.
Alan W. Bernheimer, Ph.D.
Junius B. Bird
Richard J. Block, Ph.D.
Chandler McC. Brooks, Ph.D.
Elmer G. Butler, Ph.D.
Victor Cabasso, D.Sc.
Erwin Chargaff, Ph.D.
Alfred L. Copley, M.D.
Donald P. Costello, Ph.D.
Frederick, Coykendal, C.E., A.M., LL.D.
Lloyd F. Craver, M.D.
Raymond W. Cunningham, Ph.D.
William Dameshek, M.D.
Savino Albert D'Angelo, Ph.D.
Leo M. Davidoff, M.D.
Edwin John DeBeer, Ph.D.
Moses Diamond, D.D.S.
Benjamin Minge Duggar, Ph.D.
Abraham Edelmann, Ph.D.
Sidney Farber, M.D.
Wallace Osgood Fenn, Ph.D.
Maxwell Finland, M.D.
Richard M. Fraps, Ph.D.
Jules Freund, M.D.
Jeanne G. Gilbert, Ph.D.
Anna Goldfeder, Ph.D.
Winifred Goldring, D.Sc.
Kurt Goldstein, M.D.
Samuel M. Gordon, Ph.D.
Ulysses S. Grant, Ph.D.
Paul György, M.D.
Benjamin Harrow, Ph.D.
Alfred C. Hawkins, Ph.D.
Sanford B. Hooker, M.D.
Martin E. Hultquist, Ph.D.
Morris B. Jacobs, Ph.D.
Glenn L. Jepson, Ph.D.
Austin Joyner, M.D.
Erwin L. Jungherr, D.M.V.
Sophia J. Kleegman, M.D.
Vera Koehring, Ph.D.
S. Benedict Levin, Sc.B., E.M.
Michael Levine, Ph.D.
John T. Litchfield, Jr., M.D.
Walsh McDermott, M.D.
John F. Mahoney, M.D.
Floyd S. Markham, Ph.D.

Alfred Marshak, Ph.D.
Edwin B. Matzke, Ph.D.
Rudolph L. Mayer, M.D.
Henry Milch, M.D.
William Montagna, Ph.D.
Stuart Mudd, M.D.
Hans Mueller, Sc.D.
Charles W. Mushett, Ph.D.
Joseph B. Niederl, Ph.D.
Charles R. Noback, Ph.D.
Ernst A. Oppenheimer, M.D.
Sidney Paige
Hans Panofsky, Ph.D.
Elaine P. Ralli, M.D.
Frederick Reiss, M.D.
John E. Scarff, M.D.
Morris Schaeffer, M.D., Ph.D.
Stanley Schneierson, M.D.
Hans Selye, M.D., Ph.D., D.Sc.
Elmer L. Sevringhaus, M.D.
Roman Smoluchowski, Ph.D.
Fred D. Stimpert, Ph.D.
E. L. R. Stokstad, Ph.D.
Edwin Way Teale, A.M.
Selman A. Waksman, Ph.D. Sc.D.
Robert K. Waller, M.D.
J. Franklin Yeager, Ph.D.
Frederick F. Yonkman, Ph.D., M.D.
Alexander Zeissig, D.V.M., Ph.D.
Benjamin William Zweifach, Ph.D.

Honorary Life Membership was conferred upon the following eminent scientists:

Hans Cloos, Professor, Geology and Paleontology, Reinische Friedrich Wilhelms Universitats, Bonn, Germany.

Sir Howard Walter Florey, Professor of Bacteriology, Sir William Dunn, School of Pathology, University of Oxford, England.

Ludwik Hirzfield, Professor and Head of the Department of Microbiology, School of Medicine, University of Wroclaw, Poland.

Constantin Levaditti, Director of Institut Fournier, Paris, France.

Henri Pieron, Director and Professor, Institut de Psychologie, University of Paris, France.

Gaston Leon Ramon, Retired Director, Pasteur Institute at Garches, S. et G., France.

Rudolf Stefan Jan Weigl, Director of Microbiology Institute, University of Cracow, Poland.

ELECTION OF OFFICERS

The following officers were elected for the year 1949:

For President

VICTOR K. LAMER

For Vice-Presidents

GEORGE B. PEGRAM

JOSEPH C. HINSEY

For Chairmen of Sections

MAURICE EWING
CHARLES R. SCHROEDER
FREDERICK REISS
CLAIRETTE P. ARMSTRONG
JUNIUS B. BIRD
LEO SHEDLOVSKY
HANS PANOFSKY

For Recording Secretary

HARRY A. CHARIPPER

For Corresponding Secretary

RALPH H. CHENEY

For Treasurer

ROBERT F. LIGHT

For Editor

ROY WALDO MINER

For Councilors (1949–1951)

WALTER ROOT
JOHN TEE VAN
W. G. BYWATER

For Finance Committee

ADDISON WEBB, *Chairman*
JOSEPH W. BARKER
GORDON BILLIARD

PROGRAM OF THE EVENING

After the Business Meeting, the following program was given:

Presentations. A portrait of Sir Alexander Fleming, discoverer of Penicillin, was presented to the Academy by the artist, Bernard Godwin, acting on behalf of an anonymous donor. After the Academy has secured its proposed new building this portrait will be hung there in a place of honor.

America's Future Oil Supplies. By ROBERT E. WILSON, Chairman of the Board, Standard Oil Company (Indiana)

Recording Sounds of Undersea Life. By MILTON B. DOBRIN, Department of Geology, Columbia University

RECORDING SOUNDS OF UNDERSEA LIFE

By MILTON B. DOBRIN*

The fact that a geophysicist has been asked to give an address on a subject most properly classified under biology shows how the established division lines between the branches of science are no longer applicable to many modern lines of research. It is fortunate, for this reason, that there are organizations such as the New York Academy of Sciences, where the emphasis is on the unity of scientific knowledge rather than its artificial partitioning.

The ability of some fish to make noise under water has been recognized since the time of the ancient Phoenicians, whose fishermen are said to have located schools of drumfish in the Mediterranean by listening for their sounds. Primitive fishermen in the Malayan seas still make use of an ancient technique described in a communication from David G. Stead of Australia as follows:

"The head man of the fishing crew gets out over the side of the fishing prau and holds on with his head under water, listening until he locates (by their honking) the fish. The net is then cast round them on the bottom. Meanwhile a very heavy gong is being operated on by a man in the prau, and the booming and thrumming from this are conveyed through the water to the fish, which huddle together and are more easily caught in the bag of the net."

In this country, even the common names of many fish species, such as the croaker, hogfish, toadfish, red drum, and grunt, are indicative of their sonic abilities. Fishermen along our east coast and Gulf coast have heard these and other noise-making fish sound off as they were pulled out of the water in nets. In spite of this, the fact that fish make noise at all does not seem generally known, as the continued popularity of the expression, "silent as a fish," testifies.

Until the start of the recent war, the subject of noise production by marine life was virtually unexplored by science. It required the exigencies of the war to point up how little information was available in the scientific literature on the nature and magnitude of sounds created under water by fish and crustacea. Such information became necessary when it was discovered that biological noises were often interfering with the underwater acoustic devices introduced early in the war both for offensive and defensive purposes.

Among these devices were submerged microphones at harbor entrances which could pick up propeller noises from any

* Department of Geology, Columbia University, New York, N. Y. and U. S. Naval Ordnance Laboratory, Washington, D. C. This paper, accompanied by recordings, was presented before the 131st Annual meeting of the New York Academy of Sciences on December 15, 1948.

enemy ships or submarines which might attempt to sneak into the harbors under cover of fog or darkness. In all seas, our patrol vessels countered the submarine menace by scanning surrounding waters with rotating sonar beams. Inaudible to the human ear, these supersonic beams were reflected by submerged submarines which would thus unwittingly reveal their presence and location. On the offensive side, mines were laid on the bottom with mechanisms which would blow them up when the sound level from the propeller of a ship above it reached a sufficient magnitude.

One of the earliest underwater sound installations introduced during the war was a hydrophone network set up off Fort Monroe to protect the entrance to Chesapeake Bay. During the late winter of 1942 the system worked very well indeed, yielding signals only when ships actually crossed the underwater array. But when spring came all this changed. Every evening the speakers on the surface would yield a babel of indiscriminate noises which resembled, more than anything else, the sound of a pneumatic drill tearing up pavement. The worst of it was that these extraneous noises masked the ship sounds completely and the whole system was useless for harbor protection. The army officers operating the system were baffled and called on the newly organized Office of Scientific Research and Development for help. A team of acoustics experts was rushed to the spot by the U. S. Navy Underwater Sound Laboratory at New London, Conn. They, too, were perplexed, but it did occur to one of them that fish might be responsible, and Dr. C. H. Blake, a marine biologist from M. I. T., was called in to investigate the possibility. Almost immediately, he found that the principal malefactors were indeed fish, specifically, large schools of croakers which had just come into the Bay after spawning in the open ocean. The acoustics experts measured the pitch of the fish noises and decided that they could be eliminated by a suitable electric filter which would cut out the fish noises, but let through the ship noises. After this was built and installed, no more fish were mistaken for ships, or vice versa.

About the same time engineers from the Naval Ordnance Laboratory in Washington were carrying on their own underwater listening tests at a nearby location in Chesapeake Bay. Their primary interest was in developing acoustic mine mechanisms. They too were bothered by the extraneous noises which had made so much trouble at Fort Monroe, and they were concerned by the implications of Dr. Blake's discovery that schools of fish could be responsible for louder noises under water than could be obtained from the propeller of a nearby ship. This meant that an acoustic mine might well be fired by fish long before a ship would ever come near. The Naval Ordnance Laboratory consequently initiated an extensive study of biological water noises that continued for nearly two years.

The first tests under this program gave some interesting information on the diurnal and seasonal variation of the fish noises in the Chesapeake. During the day, there was virtually no noise in the water, but with the coming of evening the sounds began and increased in intensity steadily until they reached their maximum loudness at about 8:30 P. M. After this time, they would fall off rapidly, until by midnight the noises were all but gone. The reason for this well defined evening crescendo and subsequent diminuendo, repeated night after night, is still not known, but they appear to have some relation to the croakers' feeding habits. Seasonal variations were not quite as smooth as the diurnal changes, but there were well defined

trends. The nightly maxima, scarcely perceptible in early May, increased steadily until their peak value was reached about June 5. The intensities gradually fell off after this date until by mid-July the nightly choruses were no longer to be heard.

Meanwhile, on the west coast, a group from the U. S. Navy Radio and Sound Laboratory in San Diego ran into difficulties while testing high frequency sonar wave transmission. Where the ocean was deep, reflections were detectable from ships and submarines at much greater distances than in the shallow water with rocky bottoms characteristic of the California coast. Seeking the cause of this anomaly, the Navy engineers discovered that wherever the water was shallow a hydrophone would pick up an incessant noise similar to that of dry twigs crackling in a fire. This noise, by masking reflections from submarines, cut the range of sonar's effectiveness. Suspecting a biological origin, University of California marine zoologists under Prof. Martin Johnson caught specimens of every kind of marine life known to exist in the area, put them in aquarium tanks with hydrophones, and listened. After several months of failure, the culprit was discovered. It was the snapping shrimp, genus *Crangon*, a type of shrimp considerably different from the one we ordinarily eat. It is a tiny round crustacean less than half an inch in diameter with two claws of unequal size, the larger being the most conspicuous feature of its anatomy. By clicking together the two parts of this claw in the water, the creature makes an underwater pop comparable to the noise created when a swimmer clicks two stones together.

The total number of *Crangon* in the world must be a truly astronomic figure, since the crackling noises have been picked up wherever there have been underwater listening tests in marine waters less than 100 feet deep, between latitudes 35° N and 35° S.

As the war progressed, the tactical aspects of the biological noise problem changed somewhat. The Navy became more concerned with interference from the species inhabiting East Indian and Japanese waters than from those of Chesapeake Bay or San Diego Harbor. It was, of course, impracticable to record and measure noises from fish actually in strategic waters, therefore the next best solution was tried, namely listening to accessible fish resembling most closely those sonic species known to inhabit the seas surrounding enemy shores. Tests were accordingly conducted around Hawaii and the southwest Pacific islands, in home waters, and even in aquaria. Rather than to discuss all of these in detail, the author prefers to limit the remainder of his narrative to the small part of the total program with which he was personally involved.

The first of the projects in which he participated was in the world's largest aquarium, the John G. Shedd in Chicago. The Naval Ordnance Laboratory sent half a ton of sound equipment and two observers to this point, nearly 1,000 miles from salt water, to record the noises, if any, made by the marine specimens in captivity there. We managed to record some kind of noise from more than half the species in the aquarium, although some of these consisted only of crunching sounds at feeding time.

In the early summer of 1943, the Naval Ordnance Laboratory sent a party to the U. S. Fishery Biological Laboratory at Beaufort, N. C. with the principal mission of segregating various sonic fish species and recording the noises of each kind alone. The scheme was to send out fishermen who would bring back their catch alive, sorting out the different species into staked off enclosures in a salt water pond. An eavesdropping hydrophone would then

be moved from one enclosure to another. Up until now, only the croaker had definitely been identified as a major contributor to the chorus of underwater noises picked up by hydrophones in east coast waters. Now we were trying to isolate the other culprits. Beaufort was chosen for this on account of its location near Cape Lookout, where the Gulf Stream leaves the coast line and starts across the Atlantic. At such a junction point, both tropical species brought up by the Stream and northern species live in close proximity.

Our first project at Beaufort was to listen to the normal water noises heard in Bogue Sound at that time of year, and this was done simply by hanging a hydrophone off the edge of the main pier on the Laboratory grounds. From the beginning, the variety and intensity of sounds was amazing. The drum rolls previously picked up in Chesapeake Bay from the croakers were heard, but, in addition, there were cackles, honks, crackles, and, most mysterious of all, periodic musical toots which resembled the sound of a fog horn and which occurred regularly about every five seconds, each toot lasting about a second. Sometimes, the toots would come in pairs, the second sounding as if it were in answer to the first. Additional listening posts were set up at Fort Macon on the inlet connecting Bogue Sound with the open sea, as well as on Coast Guard patrol boats which anchored in the ocean as much as 20 miles outside the inlet.

For our tests on the segregated fish, we staked off four enclosures with wire in an abandoned mullet pond and put representatives of a separate species in each. As tests were completed on a species, we netted out the specimens from its enclosure, replacing them with members of a new species.

About ten species made recordable noises. The croakers gave the familiar drum rolls, but with much less spirit and vehemence in captivity than when swimming freely in the waters outside. The black drum made a sound that was very much like that of the croaker. The sea robin, a red species looking almost as much like a bird as a fish, made a sound that resembled both a dog barking and a goose cackling. The spot gave intermittent honks that sounded something like "Bronx cheers." The hogfish grunted, just as one would expect from its name. The catfish produced a rhythmic drumming with the cadence of a tom-tom. The hardest noise to identify definitely was the strange musical toot, previously mentioned, which sounded like a fog horn and was heard almost incessantly around the Fishery Laboratories pier. The natives of the area said that the noise, which could be quite easily detected by anyone standing on the pier, came from the toadfish. But of the many toadfish we caught and transferred to the mullet pond, none would make any noise at all.

Then one day the loud speaker connected to the hydrophone off the Fishery pier began to give out a much louder "foghorn" toot than it ever had before at that gain setting and the needle of the recording meter jumped violently off-scale with each blast. Strangest of all, the source seemed to remain in one place for days, since the volume and cadence stayed the same for more than a week. The fact that the source apparently did not move suggested that it might indeed be a toadfish, since this species is a bottom dweller which builds nests in pipes or tin cans and remains in them for long periods. The identity of the noisemaker was finally established to our satisfaction, but in an indirect and circumstantial way. We lowered a baited crab trap into the water next to the hydrophone into which the loud "foghorn"

noise was being emitted. A minute later, the noise stopped and the crab trap was pulled up with a toadfish inside. Yet, it was never possible to get a toadfish to sound off in captivity. Perhaps members of this species make noise only when guarding their eggs, the very high acoustic intensity they can develop paralyzing any intruder that ventures too near.

The mechanism by which many fish make noise under water was first discovered about forty years ago by R. W. Tower, who published a paper in the Annals of The New York Academy of Sciences in 1908 on noise production in the drumfish, toadfish, and sea robin. There seem to be two principal mechanisms. The first is stridulation or grinding of the pharyngeal teeth, which explains the noise production of the hogfish, grunt, and certain coral reef species associated with tropical waters. The more significant sonic species, however, make their noises through muscular action upon their swim bladders. The drumfish, or Sciaenidae, such as the croakers or black drums, strike so-called "drumming muscles" against their swim bladders about 15 times a second and set it into resonant vibration like a drum. As a specimen grows to full length, its resonant frequency decreases, since the length of the resonating swim bladder increases. Toadfish (Batrachoididae) and sea robins (Triglidae) are said to make their noise through stridulation of the swim bladders with muscles which rub them from the outside and give out a noise somewhat like that made when one strokes a wet balloon with his finger.

A question at least as interesting as *how* fish make noise is *why* fish make noise. Does their noisemaking activity perform some function associated with their mating or feeding habits? Do the fish communicate with one another and actually convey intelligence? What is the motivation? Having worked on the biological noise problem only as a physicist, the author does not feel qualified to suggest any answers to these questions. Perhaps the hydrophone may someday become a valuable tool to those studying behavior patterns in fish.

Another interesting question is whether there might be any post-war application of the wartime discoveries made in this field. There are at least two potential ones. The first is the possible use of acoustic methods to study fish populations and movements on a statistical basis. The federal government and many state biological surveys spend large sums annually for this kind of information and it may turn out that acoustic data can provide it at a minimum of expense. Only further research can establish whether the necessary correlations exist.

The other application would be to use sound equipment as a means of assisting fishermen in locating their catch. As pointed out earlier, this has ample precedent dating back to ancient times, but it does not seem to be entirely promising. In the first place, many food fish are not sonic, the great majority north of Chesapeake Bay being quite silent. Secondly, most sound producing fish are noisy only for a few hours a day, usually at night. In the third place, it would be impossible to hear any fish as long as the fishing vessels' propellers are turning, a factor that would restrict the mobility of such fishing operations. Finally, the complexity of the present equipment would limit its acacceptance by most fishermen. Nevertheless, some manufacturers of marine equipment are considering the marketing of underwater listening kits for fishermen. Perhaps the various difficulties can be ironed out through further development and, in a matter of a few years, we will find most fisherman wearing earphones at their

work. If this should be the case, it would not be the only instance of research instigated purely by wartime necessity leading to useful and profitable peacetime applications.

Abstract: EFFECT OF CONCENTRATION ON THE VISCOSITY OF DILUTE SOLUTIONS

By DOCTOR ROBERT SIMHA*

Awarded an A. Cressy Morrison Prize, 1948

Doctor Simha's paper sets up and solves an usually difficult problem in theoretical hydrodynamics. Considering the necessary approximations, his predicted result is in good agreement with the experimental values, and we now will have a theoretical explanation of a property of solutions which has been a puzzle for a long time.

Viscosity, in Physics, is the resistance of a fluid to the movement of its molecules among themselves. These particles may be spherical but, more likely, non-spherical, and the resistance and flow of the fluid is dependent upon their shape and concentration, i.e., their nearness to each other.

The author presents a theory, represented by a power series formula, of the higher coefficients of the viscosity-concentration curve of a suspension of non-spherical particles. Starting with a simple model of dumb-bell, to represent such a non-spherical particle, the flow around a single unit and its modification due to interaction with other particles are considered.

In this paper, it is the purpose of the author, with reference to the formula above mentioned, to examine the validity of the proportional increase in complexity of the terms of the equation as expressions of the increasing complexity of the reactions of progressively increasingly numbers of particles of varying shape in their disturbance of the flow of the liquid, thus forming a measure of the intrinsic viscosity of the fluid.

* National Bureau of Standards, Washington, D. C.

Abstract: THE RELATION OF THE ADRENAL CORTEX TO THE STRUCTURE AND PHAGOCYTIC ACTIVITY OF THE MACROPHAGIC SYSTEM

By DOCTOR ALBERT S. GORDON AND MRS. GRACE F. KATSH*

Awarded an A. Cressy Morrison Prize, 1948

There is considerable evidence that the endocrine gland system plays a role in the response of the body to a wide variety of physical, chemical and microbic stresses. Hormonal administration or deficiency cause alterations in the quantities of circulating antibodies. The lymphatic system and the macrophagic tissues are implicated, as is well-known. The influence of ductless glands, however, upon the phenomenon of phagocytosis has not been thoroughly explored.

During the past two years, the authors have conducted a series of experiments on male rats to examine the influence of the adrenal cortex and the pituitary upon the structure and functional activity of the macrophagic system, through chemical analysis, histological studies and macrophagic cell counts, with especial reference to the spleen, the Kupffer cells of the liver, the lymph nodes, thymus and bone marrow. Removal of the adrenals and pituitary affects the production of phagocytes by the tissues of these organs.

* Department of Biology, Washington Square College of Arts and Sciences, New York University, New York City.

Abstract: PORTO RICAN PREHISTORY (In Two Parts)

By DOCTOR IRVING ROUSE*

Awarded an A. Cressy Morrison Prize, 1948

This paper is the result of three seasons' research on the prehistoric native inhabitants of Porto Rico and their culture, as deduced from an extensive series of excavations in all parts of that Island, by the author. The pottery unearthed, much of it in fragments, in the light of the successive layers in which it occurred and the geographical distribution of the various types into which it was carefully classified, shows that there were three prehistoric races that successively occupied Porto Rico before its discovery by the Spaniards.

The first, a primitive people, the Ciboney, migrated to Porto Rico from Florida. Their remains, indicated only by bone, rough stone, and shell implements, show that they were a non-agricultural race. They were overcome by the Arawaks, South American Indians, who entered the West Indies by way of the Lesser Antilles and the Virgin Islands. They seized possession of Porto Rico, it is believed, about the year 929 A.D., and developed an agricultural era. Their remains are abundant in the form of pottery of characteristic types which fall into two successive categories. About 1437, they were displaced by the warlike Caribs, who inhabited the region when the Spaniards came, and have left remains throughout Porto Rico in the form of later types of pottery.

Doctor Rouse's paper analyzes the evidences for this succession of cultures, and their chronological implications, with scholarly insight.

* Associate Curator, Peabody Museum of Natural History, Yale University, New Haven Connecticut.

Abstract: DRAINAGE EVOLUTION IN THE APPALACHIANS OF PENNSYLVANIA

By DOCTOR HENRY D. THOMPSON*

Awarded, the George Frederick Kunz Prize in Geology and Mineralogy, 1948

Geologists, generally agreed that the watershed between the eastward and westward flowing streams in the Pennsylvania region, before and during Upper Triassic time was far eastward of its present position, with the land much higher that at present. In fact, the main divide is now beyond the Ridge and Valley province, eighty miles or more from the crystalline rocks where it was formerly located.

During the earlier period of the elevated continent, the streams flowing eastward to the Atlantic, though much shorter than those on the west side of the divide, were much steeper in their course to the sea, and with much greater cutting power.

Doctor Thompson utilizes this feature as the beginning of his explanation of the remarkable reversal that took place in the courses of many of the streams. He states that "over a broad belt, the streams that formerly ran westward now flow eastward. How did this complete reversal take place?" Doctor Thompson argues that the superior cutting power of the steeper eastward flowing streams of the period enabled them to cut backward toward their sources, forming deepening canyons toward their head-waters and weakening the ridge of the divide by erosion, thus forcing it westward. At the same time, it invaded the head-waters of the westerly flowing streams "capturing" them and reversing their flow.

* Professor of Geology and Head of Department, Hunter College, New York City.